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Social Networks and Maximum Tongue Pressure: The Nagasaki Islands Study

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Social Networks and Maximum Tongue Pressure: The Nagasaki Islands Study

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ABSTRACT

Objectives

Social environment is often associated with health outcomes, but epidemiological evidence for its effect on oral frailty, a potential risk factor for aspiration, is sparse. This study aimed to assess the association between social environment and tongue pressure, as one of important measure of oral functions, focusing on the family structure, social networks, both with and beyond neighbors, and participation in leisure activities.

Design

A population-based cross-sectional study.

Setting

Annual health check-ups in a rural community in Japan.

Participants

A total of 1982 participants, all over 40 years old. Anyone with missing data for the main outcome (N = 14) was excluded.

Outcome measures

Tongue pressure was measured three times, and the maximum tongue pressure was used for analysis. A multivariable adjusted regression model was used to calculate parameter estimates (B) for tongue pressure.

Results

Having a social network involving neighbors (B = 2.43, p = 0.0001) and taking part in leisure activities (B = 1.58, p = 0.005) were independently associated with higher tongue pressure, but there was no link with social networks beyond neighbors (B = 0.23, p = 0.77). Sex-specific analyses showed that for men, having a partner was associated with higher tongue pressure, independent of the number of people in the household (B = 2.26, p = 0.01), but there was no association among women (B = −0.24, p = 0.72; p-interaction = 0.059).

Conclusions

Having a social network involving neighbors and taking part in leisure activities were independently associated with higher tongue pressure. Marital status may be an important factor in higher tongue pressure in men.

Keywords: Social network, Social environment, Oral frailty, Family arrangement, Marital status, Epidemiology

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Strengths and limitations of this study

- This is the first study of which we are aware to examine a possible association between tongue pressure with social environment among population-based samples.
- Social environment was measured using a unique approach, focusing on family structure, social networks both with neighbors and beyond, and leisure activities, using simple questions.
- Detailed information about social networks and leisure activities, including quality and quantity of social networks, or type of activities, was not available.
- Social environment data were self-reported, and may therefore reflect a point in time, rather than a long-term situation.
- Causal relationships cannot be inferred because of the cross-sectional design.

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INTRODUCTION

The proportion of people aged 60 years or over is expected to rise from 12% to 22% of the total global population between 2015 and 2050.[1] In Japan, it was already 33% in 2015 and is still rising.[2] Pneumonia is the third most common cause of death in Japan,[2] and often results in reduced quality of life for both pneumonia patients and their families, as well as high medical costs.[2][3] The vast majority (97%) of pneumonia deaths in Japan in 2015 were among those aged 65 years or over,[2] and most cases hospitalized for pneumonia were aspiration pneumonia.[4] Dysphagia is a main cause of aspiration,[5] and a susceptible condition for development of pneumonia in elderly people. A recent systematic review reported that estimated mean prevalence of dysphasia among community dwelling elderlies is 15% across high quality studies.[6] Dysphagia and related aspiration pneumonia prevention is therefore a public health priority in Japan and is expected to be an important issue in other countries.

Social environment refers to the immediate physical surroundings, social relationships, and cultural milieus within which defined groups of people function and interact,[7] which has a strong influence on physical and psychological health.[8] 'Social network' is one of social environment which means the structure of relationships, both quality and quantity,[9,10] including family relationships. For example, family members could have a strong influence on health[11] through lifestyle factors such as diet, economic situation, living environment, behavior, or emotions. Having a small social network has been linked to higher risk of mortality,[12,13] and incidence of cardiovascular diseases (coronary heart disease,[12,14] heart failure,[15] and stroke[10,13]). Having fewer social interactions may be associated with earlier onset of physical and/or cognitive functional disability.[16] Although some population-based studies have suggested that social relationships were associated with oral health, including number of teeth remaining, tooth decay and periodontitis,[17][18] evidence of their effect on tongue pressure is sparse. Tongue function is one of essential oral functions, and is known to have an important role in not only mastication and swallowing,[19] but also daily activities and communication, because which controls articulation and pronunciation.

Lower oral function is related to dysphagia and subsequent aspiration pneumonia.[20] Risk factors for dysphagia include age, existence of lung diseases, stroke,[21], dementia, Parkinson's disease, low tongue pressure, tooth loss, diabetes, or xerostomia,[22] use of hypertension medication, antipsychotic drugs, and malnutrition.[6] Bad oral health and poor oral hygiene have been linked to the development of aspiration pneumonia,[22][23] whereas, oral care was reported as a

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preventive factor.[23]

Previous experimental studies have shown that lingual exercise[24] had a positive influence on tongue function assessed by isometric and swallowing pressures, and lingual volume. No study, however, has examined whether social environment and daily activities are associated with tongue pressure as a potential risk factor for dysphagia and aspiration. Dysphagia and risk of aspiration has been evaluated in a hospital, measuring swallowing function by videofluoroscopic examination and videoendoscopic evaluation of swallowing, but these techniques are not useful for screening in a community. Tongue-pressure measurement has been recently identified as a useful proxy for risk of aspiration, as it assesses tongue motor function. Good reproducibility and high correlations of this measurement with other objective measurements for oral function (e.g., the repetitive saliva swallowing test, speech intelligibility test, oral diadochokinesis and capacity of tongue-holding and movement test)[25] and symptoms of dysphagia[26] have been reported.

We hypothesized that social environment and daily activities may influence tongue pressure. Using data from the Nagasaki Islands Study, we tested the hypotheses that people's social environment, including their family structure, social networks with and beyond their neighbors, and participation in leisure activities would be positively associated with higher tongue pressure, independent of physical, psychological, and behavioral risk factors for dysphagia.

METHODS

Study sample

The original sample for the cross-sectional study was participants (821 men and 1161 women) over 40 years old who attended the annual health check-ups in a rural community on the Goto Islands in western Japan in 2015 to 2016. We excluded participants without data on tongue pressure (n = 14), resulting in a final sample for analysis of 815 men and 1153 women. This study was approved by the Ethics Committee in Nagasaki University Graduate School of Biomedical Sciences (project registration number: 14051404), and all participants gave informed consent.

Measures

Tongue Pressure Measurement

The Tongue Pressure Measurement Device (JMS Co., Ltd., TPM-01) was used during health check-ups to evaluate a part of qualitative oral function by measuring maximum tongue pressure. The TPM-01 is a newly developed handheld manometry device, using

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a small balloon-type disposable oral probe with a plastic pipe, which is placed on the upper surface of the tongue. The TPM-01 is approved as the first medical device for tongue pressure measurement in Japan in 2010.[25] The reproducibility is comparable to previous experimental balloon-type manometers[25] which were examined the validity comparing to widely-used tongue pressure manometers, the Iowa Oral Performance Instrument (IOPI), and to the stable adhered three air-filled bulbs manometry system of the KayPENTAX Digital Swallowing Workstation™.[27] As a zero calibration, the probe was inflated with air at a pressure of 19.6 kPa, setting the balloon's diameter at approximately 18 mm.[27] Measurement was performed in a relaxed sitting position, and participants were asked to compress the small balloon to the palate as hard as they could, using their tongue. The maximum value was recorded automatically and displayed on the device.[27] The measurement was performed three times, and the maximum tongue pressure was used for analysis.

Social environment assessment

Social environment was assessed by questionnaire about participants' social networks and daily activities. We asked participants' family structure in the household, social networks with their neighbors and beyond, and participation in leisure activities. Family structure was assessed by number of family members in the household, and marital status. Participants were asked whether they were married, divorced, separated, or unmarried, and responses were classified dichotomously as married (having a partner) or not. Social networks were assessed by asking: Do you have any close neighbors with whom you can talk? (social network involving neighbors); Do you have any close friends, family or relatives beyond your neighbors whom you visit and who visit you? (social network beyond neighbors). Leisure activities were assessed by asking: Do you have any hobbies, interests, or leisure activities inside or outside your home? Choices for those questions were yes or no. Those three questions about social networks and leisure activities were a part of the Frailty Index for Japanese elderly.[28]

Measurement of covariates

Questionnaires were used to obtain information on age, sex, smoking status (current, former, or never), alcohol use (current, former, or never), physical exercise, psychological distress, medical history and medication use. Physical activity was assessed by asking: Have you been in the habit of doing exercise that makes you sweat lightly for over 30 minutes a time, at least twice weekly, for over a year? In your daily life, do you walk or do an equivalent amount of physical activity for more than one hour

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a day? The choices were yes or no. Participants who answered no for both questions were considered to be physically inactive, and those who answered yes for either as physically active.

Psychological distress was measured using the Kessler 6 (K6) scale, a quantifier of non-specific psychological distress.[29] Physiological variables were measured by trained technicians. Weight (kg) and height (cm) were measured in light clothes (DC-250; Tanita, Tokyo, Japan). Blood pressure was measured at rest. Hypertension was defined as diastolic blood pressure ≥ 90 mmHg, systolic blood pressure ≥ 140 mmHg, and/or self-reported antihypertensive medication use. Diabetes mellitus was defined as hemoglobin A1c ≥ 6.5%, or medication use for diabetes. History of stroke and respiratory disease were identified by self-reported medication use or having accessed medical care for those diseases.

Statistical analysis

Descriptive statistics of covariates and potential mediators, by participant's sex, were generated using analysis of variance and χ^2 tests. Spearman correlation coefficients were calculated. Multiple linear regression analysis was used to calculate total and sex-specific parameter estimates (B) for maximum tongue pressure after sequential adjustment for potential confounding variables. We used four sequential models. Model 1 adjusted for age and sex, Model 2 also adjusted for body mass index, lifestyle factors (smoking status, alcohol drinking status, and physical activity), psychological distress (K6 score) and major risk factors for dysphagia (anti-hypertensive medicine use, diabetes, and history of stroke and respiratory disease). The number of family members in the household, marital status, social networks with and beyond neighbors, and participation in leisure activities were included in the models. The average number of family members living in the household was 2.08, and 87% of participants who were living with someone were married. We also separately included number of family members in the household (Model 3) and marital status (Model 4) to avoid over-adjustment.

In sensitivity analyses, we excluded participants with a history of stroke or respiratory disease, to avoid the possibility that lower tongue pressure or overall oral function was an after-effect of those diseases. We also examined the sex-specific associations, and tested whether either sex modified the relationships of social networks and leisure activities with maximum tongue pressure, by including cross-product terms in the models (Model 2). All analyses were performed using SAS 9.4 (SAS Institute Inc.).

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RESULTS

The 1968 participants in our final sample for analysis were on average 70.6 years old (range 40 to 95), 59% female, and with a mean BMI of 23.4 kg/m^2. **Table 1** shows the characteristics of participants by sex. The mean (standard deviation, SD) maximum tongue pressure was 32.4 (10.4) kPa in men and 29.8 (9.6) kPa in women (p for difference < 0.0001). The tongue pressure was lower among older age groups in both men and women (**Figure 1**). A total of 93 (11.4%) men were classified as having a tongue pressure < 19.9 kPa, 227 (27.9%) as 20.0 to 29.9 kPa, and 495 (60.7%) as ≥30 kPa. In women, the figures were 171 (14.8%), 384 (33.3%) and 598 (51.9%). The mean number of family members in the household was greater for men (2.2 people) than women (2.0 people) (p = 0.001). The proportion of men having a partner was also higher (77% vs 63%) (p < 0.0001).

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Table 1. Participant characteristics according to sex: The Nagasaki Islands Study 2015-2016.

Sex Category	**Women**	**Men**	p for difference
N	1153	815	
Demographics			
Age, years[a]	70.4 (9.3)	70.1 (10.3)	0.44
Lifestyle Factors			
Physical Inactivity, %	14.1	17.9	0.15
Cigarette Smoking Status, %			
Never	94.0	27.0	
Former	3.8	52.5	<.0001
Current	2.2	20.5	
Alcohol Drinking Status, %			
Never	78.9	28.2	
Former	2.5	11.4	<.0001
Current	18.6	60.4	
Physiologic Characteristics			
Maximum Tongue Pressure			
Average, kPa[a]	29.8 (9.6)	32.4 (10.4)	<.0001
<20.0 kPa, %	14.8	11.4	
20 to 29.9 kPa, %	33.3	27.9	0.0004
≧30.0 kPa, %	51.9	60.7	
Body Mass Index, kg/m^2 [a]	23.2 (3.5)	23.8 (3.0)	<.0001
Hypertension Medication, %	46.8	48.2	0.54
Prevalent Diabetes, % [b]	10.5	14.4	0.01
History of Stroke, %	2.6	4.8	0.01
History of Respiratory Disease, %	2.6	3.1	0.54
Psychologic Characteristics			
Psychological distress (K6 score)[a]	1.4 (2.7)	1.1 (2.5)	0.01
Social Environments			
Number of family members in the household [a]	2.0 (1.0)	2.2 (0.8)	0.001
Marital Status (having a partner), %	63.0	77.2	<.0001
Participation in leisure activities, %	82.0	81.2	0.67
Having a Social network with neighbors, %	86.8	81.0	0.0004

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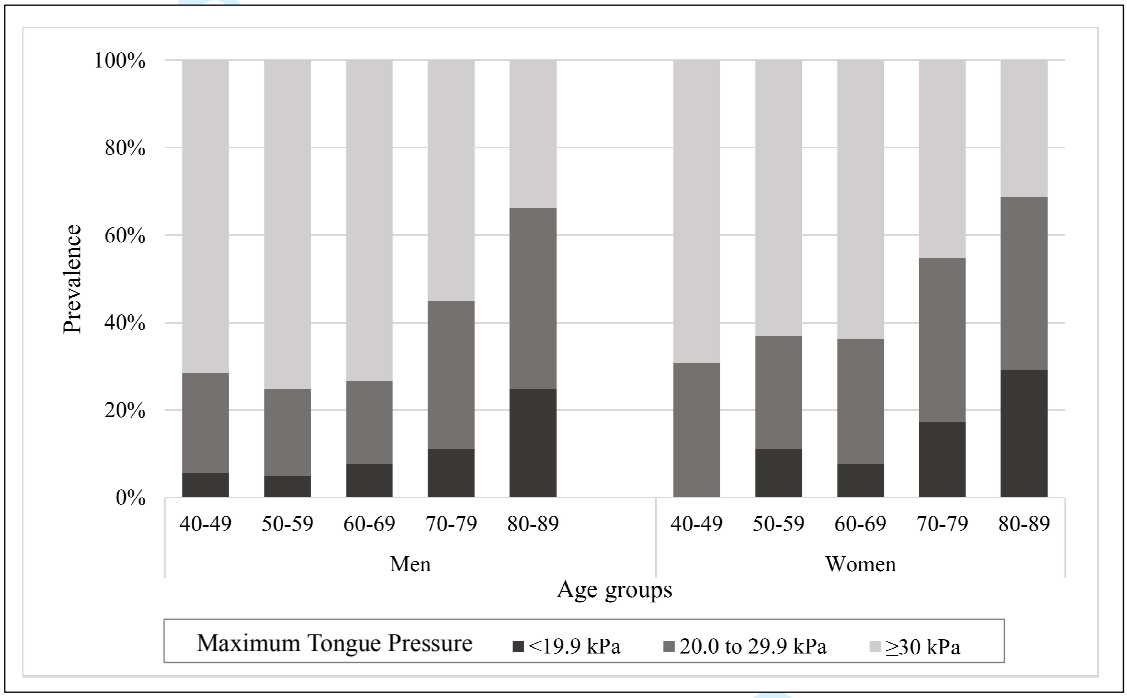
Having a Social network beyond neighbors, %	92.1	88.8	0.01

[a] Represented as mean (SD)

[b] Diabetes was defined as hemoglobin A1c ≥6.5%, or medication use for diabetes.

Figure 1. Sex-specific maximum tongue pressure according to age groups: The Nagasaki Islands Study 2015-2016.



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Using simple Spearman's correlation coefficients, the number of family members in the household was positively correlated with marital status ($r = 0.56$, $p < 0.0001$) and negatively correlated with participation in leisure activities ($r = -0.07$, $p = 0.002$) and social networks beyond neighbors ($r = -0.05$, $p = 0.03$). Marital status was correlated with social networks beyond neighbors ($r = 0.06$, $p = 0.01$), but not correlated with social networks involving neighbors or leisure activities. Taking part in leisure activities was positively correlated with social networks with and beyond neighbors ($r = 0.19$, $p < 0.0001$, and $r = 0.16$, $p < 0.0001$), and the two types of social network were also correlated ($r = 0.35$, $p < 0.0001$).

Social Environment and Maximum Tongue Pressure among Participants

Multivariable adjusted linear regression analysis showed that social network involving neighbors and participation in leisure activities were positively associated with higher tongue pressure; the respective multivariable adjusted parameter estimates (B) were 2.43 ($p = 0.0001$) and 1.58 ($p = 0.005$) (**Table 2**, Model 2). The number of family members in the household, marital status and social network beyond neighbors were not associated with maximum tongue pressure. The associations did not change when we separately included number of family members in the household (Model 3) and marital status (Model 4).

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Table 2. Association of Social Environments with Maximum Tongue Pressure: The Nagasaki Islands Study 2015-2016.

	Model 1[a]			Model 2[b]			Model 3[c]			Model 4[c]		
Social Environments	B	95 % CI	p value	B	95 % CI	p value	B	95 % CI	p value	B	95 % CI	p value
TOTAL												
Number of family members in the household	-0.45	(-0.97, 0.07)	0.09	-0.44	(-0.95, 0.07)	0.09	-0.32	(-0.78, 0.15)	0.18	-	-	-
Marital Status	0.49	(-0.52, 1.50)	0.34	0.59	(-0.42, 1.59)	0.25	-	-	-	0.30	(-0.62, 1.21)	0.53
Participation in leisure activities	**1.90**	**(0.78, 3.01)**	**0.001**	**1.58**	**(0.48, 2.68)**	**0.005**	**1.60**	**(0.51, 2.70)**	**0.004**	**1.61**	**(0.52, 2.71)**	**0.004**
Social network with neighbors	**2.60**	**(1.35, 3.85)**	**<.0001**	**2.43**	**(1.19, 3.67)**	**0.0001**	**2.41**	**(1.18, 3.65)**	**0.0001**	**2.37**	**(1.14, 3.60)**	**0.0002**
Social network beyond neighbors	0.55	(-1.01, 2.11)	0.49	0.23	(-1.30, 1.77)	0.77	0.32	(-1.21, 1.85)	0.68	0.36	(-1.17, 1.88)	0.64
Women												
Number of family members in the household	-0.13	(-0.77, 0.51)	0.69	-0.18	(-0.82, 0.46)	0.58	-0.23	(-0.81, 0.35)	0.44	-	-	-
Marital Status	-0.34	(-1.62, 0.93)	0.60	-0.24	(-1.51, 1.04)	0.72	-	-	-	-0.30	(-1.47, 0.86)	0.61
Participation in leisure activities	**1.61**	**(0.18, 3.03)**	**0.03**	1.42	(-0.01, 2.84)	0.05	1.41	(-0.01, 2.83)	0.05	1.41	(-0.02, 2.83)	0.05
Social network with neighbors	**2.73**	**(1.07, 4.39)**	**0.001**	**2.67**	**(1.00, 4.33)**	**0.002**	**2.68**	**(1.01, 4.34)**	**0.002**	**2.63**	**(0.97, 4.29)**	**0.002**
Social network beyond neighbors	1.15	(-0.93, 3.23)	0.28	1.17	(-0.90, 3.23)	0.27	1.13	(-0.92, 3.19)	0.28	1.23	(-0.82, 3.27)	0.24

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Men												
Number of family members in the household	**-1.03**	**(-1.92, -0.14)**	**0.02**	-0.81	(-1.68, 0.07)	0.07	-0.37	(-1.17, 0.44)	0.37	-	-	-
Marital Status	**2.65**	**(0.85, 4.45)**	**0.004**	**2.26**	**(0.47, 4.04)**	**0.01**	-	-	-	1.61	(-0.02, 3.23)	0.05
Participation in leisure activities	**2.12**	**(0.35, 3.90)**	**0.02**	1.73	(-0.02, 3.48)	0.05	**1.90**	**(0.15, 3.65)**	**0.03**	**1.89**	**(0.15, 3.63)**	**0.03**
Social network with neighbors	**2.43**	**(0.51, 4.34)**	**0.01**	**2.13**	**(0.25, 4.02)**	**0.03**	**2.14**	**(0.25, 4.03)**	**0.03**	**2.04**	**(0.15, 3.92)**	**0.03**
Social network beyond neighbors	-0.26	(-2.66, 2.14)	0.83	-1.02	(-3.39, 1.35)	0.40	-0.74	(-3.11, 1.63)	0.54	-0.96	(-3.32, 1.40)	0.43

The number of family members in the household, marital status, social networks with and beyond neighbors, and participation in leisure activities were included in the Model 1 - Model 4.

[a] Model 1: Adjusted for age and sex.

[b] Model 2: Adjusted for Model 1 + lifestyle factors (physical activity, smoking status, drinking status) + physiologic characteristics (body mass index) + psychological distress (K6 score) + major dysphagia risk factors (anti-hypertensive medicine use, diabetes, history of stroke, respiratory disease)

[c] Model 3-4: Adjusted for the same variables in Model 2 other than number of family members in the household and marital status, which were separately included in the Model 3 and Model 4 to avoid over adjustment.

B = parameter estimate.

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Sex-Specific Association in Social Environment and Maximum Tongue Pressure

In the sex-specific multivariable adjusted linear regression analyses, the associations between maximum tongue pressure and either social networks involving neighbors or participation in leisure activities were similar to the overall figures for women and men. The multivariable adjusted B values were 2.67 (p = 0.002) and 1.42 (p = 0.05) for women, and 2.13 (p = 0.03) and 1.73 (p = 0.05) for men (**Table 2**, Model 2). Social networks beyond neighbors was not associated with tongue pressure at all, whereas number of family members in the household tended to be negatively associated (B = -0.81, p = 0.07), and marital status (having a partner) was significantly positively associated with higher tongue pressure in men (B = 2.26, p = 0.01), but not women (B = -0.18, p = 0.58, and B = −0.24, p = 0.72, respectively). When we separately included number of family members in the household (Model 3) and marital status (Model 4), the associations were attenuated in men, but those attenuations did not alter the relationships of social networks and participation in leisure activities with tongue pressure.

In sensitivity analyses excluding participants with stroke or respiratory disease to exclude influences on tongue pressure or overall oral function from those diseases or associated medication, the results did not change overall or sex-specifically (**Supplemental Table 1**). There was no evidence that sex modified the relationship of number of family members in the household, networks with and beyond neighbors and leisure activities with maximum tongue pressure (interaction p ≥ 0.19). It did, however, show a borderline significant interaction in the association between marital status and maximum tongue pressure (interaction p = 0.059).

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DISCUSSION

In this population-based study of 1968 participants, having a social network involving neighbors and participating in leisure activities were associated with higher maximum tongue pressure. This association was independent of age, sex, body mass index, psychological distress, behavioral factors, and other risk factors for dysphagia. Having a partner was associated with greater tongue pressure in men only. This is the first evidence of which we are aware that suggests that social environment may influence tongue pressure. It supports previous reports suggesting the importance of social ties and taking part in daily leisure activities in improving or maintaining tongue function and possible prevention of dysphagia and aspiration.

Our results are consistent with previous studies on daily and social activities, in which oral function was assessed by self-reported questionnaire.[30][42] Kamakura et al carried out a questionnaire survey among 769 local senior club members, and reported that factors related to daily activities such as time spent outside the home each day, higher frequency of loud laughing, and enjoying eating were associated with a lower proportion of swallowing problems (self-reported choking on food).[30] A previous community-based study of 1,405 randomly selected older people showed that not participating in social activities was linked to a self-assessed masticatory problem.[42]

Although the mechanisms underlying the association between social networks or participation in leisure activities and tongue pressure have not been fully elucidated, physiological, behavioral, and psychological factors are likely to be involved. Higher activity in muscles around the pharynx and mouth may have a positive effect on tongue function. People who are living with family members and have close neighbors may communicate with others more often, and particularly have more opportunity to eat together, have conversations and laugh. Eating with someone could have a positive influence on oral function via increased saliva production and higher tongue activity, as well as having a preventive effect on depression.[31] It may also be related to better nutrition, eating behavior, dietary composition and energy levels,[32] as well as more social interactions.[33] A link was identified between laughter and enjoying eating and lower self-reported symptoms of aspiration in an epidemiological study.[30]

The difference in frequency of social interactions in daily life could be the reason why only social networks involving neighbors, and not those beyond, were associated with higher tongue pressure in this study. Although the influence of social networks beyond neighbors on tongue pressure could depend on both the type of

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relationship (close family, wider relatives, or friends) and frequency of meeting, the results suggest a possibility that an effective public health intervention to prevent oral frailty and subsequent aspiration might focus on social networks involving neighbors. Hikichi et al. reported that community intervention may be effective in encouraging social participation among Japanese older people, and helping to prevent the onset of functional disability.[16] That study confirmed that the number of community-based centers for older people, so-called 'community salons', within 350 meters of the home was related to frequency of participation. It also found that incidence of functional disability among residents who participated in 'community salons' three or more times over the 4.9 years of follow-up was reduced by 50% over those who participated twice or less. The result was similar even when the researchers accounted for the possibility of selection bias by using propensity score matching analysis and instrumental variable analysis.[16]

Although the number of family members in the household was not associated with tongue pressure in total subjects, and a negative association was observed in men in this study, we think this may be partially because of possible difference in duration of living with family members. There is also a possibility of reverse causation: some people may have started to live with family members as a result of decreased ability to perform activities of daily living. We did not collect any detailed information about leisure activities, but these could be related to social interaction, physical activity, self-actualization or 'Ikigai', a comprehensive Japanese concept encompassing the 'meaning of life' and/or 'purpose in life'.[34] Large population-based longitudinal studies of older people in Japan reported that having hobbies or social participation may be effective in decreasing the risk of functional disability,[35] and progression of senility associated with dementia.[36] A previous report from the Japanese government showed that people with more friends had a stronger feeling of 'Ikigai'.[37] Although there were correlations between social networks and participation in leisure activities in our study, the associations with higher tongue pressure were likely to be independent. The reason for the sex difference in the association between marital status and tongue pressure is unknown, but health-related behaviors could partially mediate the association. Health-compromising behaviors (e.g., smoking, heavy drinking, lower vegetable consumption and less frequent dental visits) have previously been shown to be related to marital status in both men[38,39] and women.[39,40] Marital termination (e.g., divorce and widowhood) were associated with an elevated mortality risk for men, but not for women.[41]

The association between tongue pressure and both social networks and

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participation in leisure activities were independent of psychological distress in this study. A previous study suggested that psychological distress could influence oral function via lower frequency and number of communications, related to reduced social interaction,[42] as well as altered health-promoting behaviors (e.g., brushing teeth, consuming a healthy diet, exercising, not smoking). Medication use for depression is also known to be a risk factor for dysphagia and aspiration because of the muscle relaxant effect. A future study examining links with medication use for depression may be helpful.

Strengths and Limitations

Our study had several limitations. As social networks and participation in leisure activities were assessed using a dichotomous answer, detailed information about the social network quality (e.g., relationship or closeness) and quantity (e.g., number of social networks, and frequency of communications), or the type of activity (e.g., solo or social activity) were not available in this study. However, the simplicity of the question is useful in identifying people with at least one social network or leisure activity. Further studies will be needed to investigate the influence of various detailed aspects of social networks and leisure activities on tongue pressure. Second, measurement error and subsequent misclassification almost certainly occurred, because the social environment data were self-reported. Participants' answers were about their mental and social environment at the point of response, and further studies will therefore be needed to assess the duration of the situation (e.g., how long they have been living alone) and timing (e.g., when they lost their partner, or retired). Third, although tongue-pressure measurement has good reproducibility and high correlations with other objective measurements for oral functions,[25] unmeasured characteristics of the participants like cognitive decline, or oral conditions like denture use could have influenced the measurement. Fourth, although we adjusted for potential confounders including disease-related dysphagia risk (stroke, and respiratory disease), there may have been other residual or unmeasured confounders (for example, other diseases like dementia, epilepsy, medication use including anticholinergics, diuretics, antidepressant or sleep medicine, as well as diet and lifestyle changes) that influenced the association between social environment and tongue pressure. Fifth, causal relationships cannot be identified from cross-sectional analyses. It is possible that people without oral frailty tend to maintain larger social networks or participate in more daily activities, or that some people started to live with family members as a result of weakened physical function, but this cannot be assessed. Last, our study subjects were from a rural area in Japan, in

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which social ties with neighbors could be stronger than those in urban areas. Further research would be needed to assess the generalizability of the study.

The strengths of our study included objective measurement of tongue pressure using population-based samples, a comprehensive assessment of social environment focusing on family structure, social networks within and beyond neighbors, and participation in leisure activities, and standardized data collection for potential risk factors for dysphagia including psychological distress, and physical and behavioral characteristics.

CONCLUSIONS

Having a social network involving neighbors and taking part in leisure activities were independently associated with higher maximum tongue pressure, in a sample of community-dwelling men and women. Marital status may be also an important factor in maintaining tongue pressure among men. Further studies will be needed to assess the impact of particular elements of the social environment on tongue pressure, including social network size, quality and duration of the situation, or type of activities, using a prospective design. This study, however, suggests the importance of family structure, social networks with and beyond neighbors, and participation in leisure activities for risk assessment of oral frailty.

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Competing interests

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All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

Authors' contributions

MN conceived the study, analyzed and interpreted the data, drafted the manuscript, and provided statistical expertise. MN, MH, NT, MT, JK, HY, KK, SS, ZK, TM acquired the data. MN, MH, NT, MT, JK, HY, KK, SS, SK, ZK, TM interpreted the data and critically revised the manuscript. TM is guarantor for the study. All authors approved the final version of the paper.

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Social Networks and Maximum Tongue Pressure: The Nagasaki Islands Study

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Supplemental Table 1. Association of Social Environments with Maximum Tongue Pressure among participants without history of stroke or respiratory disease: The Nagasaki Islands Study 2015-2016.

	Model 1[a]			Model 2[b]			Model 3[c]			Model 4[c]		
Social Environments	β	95 % CI	p value	β	95 % CI	p value	β	95 % CI	p value	β	95 % CI	p value
TOTAL												
Number of family members in the household	**-0.62**	**(-1.18, -0.06)**	**0.03**	**-0.65**	**(-1.20, -0.10)**	**0.02**	**-0.50**	**(-1.00, 0.00)**	**0.05**	-	-	-
Marital Status	0.56	(-0.50, 1.61)	0.30	0.65	(-0.40, 1.70)	0.22	-	-	-	0.19	(-0.76, 1.13)	0.70
Participation in leisure activities	**1.99**	**(0.84, 3.14)**	**0.001**	**1.67**	**(0.54, 2.81)**	**0.004**	**1.71**	**(0.57, 2.84)**	**0.003**	**1.73**	**(0.60, 2.86)**	**0.003**
Social network with neighbors	**2.65**	**(1.37, 3.94)**	**<.0001**	**2.45**	**(1.17, 3.72)**	**0.0002**	**2.43**	**(1.16, 3.71)**	**0.0002**	**2.36**	**(1.09, 3.64)**	**0.0003**
Social network beyond neighbors	0.46	(-1.15, 2.08)	0.57	0.12	(-1.46, 1.71)	0.88	0.21	(-1.37, 1.79)	0.79	0.26	(-1.32, 1.84)	0.75
Women												
Number of family members in the household	-0.25	(-0.95, 0.46)	0.49	-0.38	(-1.08, 0.32)	0.29	-0.45	(-1.08, 0.18)	0.16	-	-	-
Marital Status	-0.48	(-1.82, 0.86)	0.48	-0.29	(-1.63, 1.05)	0.67	-	-	-	-0.54	(-1.75, 0.66)	0.38
Participation in leisure activities	**1.63**	**(0.15, 3.10)**	**0.03**	1.44	(-0.04, 2.91)	0.06	1.43	(-0.05, 2.90)	0.06	1.42	(-0.05, 2.90)	0.06
Social network with neighbors	**2.84**	**(1.13, 4.54)**	**0.001**	**2.69**	**(0.98, 4.40)**	**0.002**	**2.69**	**(0.98, 4.40)**	**0.002**	**2.62**	**(0.91, 4.33)**	**0.003**
Social network beyond neighbors	1.27	(-0.88, 3.41)	0.25	1.37	(-0.75, 3.50)	0.21	1.34	(-0.78, 3.46)	0.22	1.45	(-0.67, 3.57)	0.18

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Men												
Number of family members in the household	**-1.22**	**(-2.14, -0.30)**	**0.01**	**-1.00**	**(-1.90, -0.10)**	**0.03**	-0.50	(-1.33, 0.34)	0.24	-	-	-
Marital Status	**3.08**	**(1.22, 4.95)**	**0.001**	**2.59**	**(0.74, 4.43)**	**0.01**	-	-	-	**1.79**	**(0.10, 3.48)**	**0.04**
Participation in leisure activities	**2.36**	**(0.52, 4.20)**	**0.01**	**1.96**	**(0.16, 3.77)**	**0.03**	**2.16**	**(0.35, 3.97)**	**0.02**	**2.15**	**(0.35, 3.95)**	**0.02**
Social network with neighbors	**2.55**	**(0.58, 4.52)**	**0.01**	**2.19**	**(0.25, 4.12)**	**0.03**	**2.15**	**(0.21, 4.09)**	**0.03**	**2.04**	**(0.11, 3.98)**	**0.04**
Social network beyond neighbors	-0.75	(-3.24, 1.74)	0.55	-1.65	(-4.11, 0.81)	0.19	-1.27	(-3.73, 1.18)	0.31	-1.54	(-3.99, 0.92)	0.22

The number of family members in the household, marital status, social networks with and beyond neighbors, and participation in leisure activities were included in the Model 1 - Model 4.

[a] Model 1: Adjusted for age and sex.

[b] Model 2: Adjusted for Model 1 + lifestyle factors (physical activity, smoking status, drinking status) + physiologic characteristics (body mass index) + psychological distress (K6 score) + major dysphagia risk factors (anti-hypertensive medicine use, diabetes)

[c] Model 3-4: Adjusted for the same variables in Model 2 other than number of family members in the household and marital status, which were separately included in the Model 3 and Model 4 to avoid over adjustment.

B = parameter estimate.

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STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-7
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	N/A
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	N/A
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5-7
Bias	9	Describe any efforts to address potential sources of bias	7, 17-18
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7
		(*b*) Describe any methods used to examine subgroups and interactions	7
		(*c*) Explain how missing data were addressed	5
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	5
		(*e*) Describe any sensitivity analyses	7

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Results			Page #
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	8
		(b) Give reasons for non-participation at each stage	5
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8-11, Table 1, Figure 1
		(b) Indicate number of participants with missing data for each variable of interest	5
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	N/A
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	N/A
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	N/A
		Cross-sectional study—Report numbers of outcome events or summary measures	11-14, Table 1-2, Supplemental Table 1
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	8, Table 2, Supplemental Table 1
		(*b*) Report category boundaries when continuous variables were categorized	N/A
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	14, Supplemental Table 1
Discussion			
Key results	18	Summarise key results with reference to study objectives	15-18
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	17-18
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	15-18
Generalisability	21	Discuss the generalisability (external validity) of the study results	17-18
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	18

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*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

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Social Networks, Leisure Activities and Maximum Tongue Pressure: Cross-sectional Association in The Nagasaki Islands Study

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Social Networks, Leisure Activities and Maximum Tongue Pressure: Cross-sectional Associations in The Nagasaki Islands Study

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ABSTRACT

Objectives

Social environment is often associated with health outcomes, but epidemiological evidence for its effect on oral frailty, a potential risk factor for aspiration, is sparse. This study aimed to assess the association between social environment and tongue pressure, as an important measure of oral function. The study focused on family structure, social networks both with and beyond neighbors, and participation in leisure activities.

Design

A population-based cross-sectional study.

Setting

Annual health check-ups in a rural community in Japan.

Participants

A total of 1982 participants, all over 40 years old. Anyone with missing data for the main outcome (N = 14) was excluded.

Outcome measures

Tongue pressure was measured three times, and the maximum tongue pressure was used for analysis. A multivariable adjusted regression model was used to calculate parameter estimates (B) for tongue pressure.

Results

Having a social network involving neighbors (B = 2.43, p = 0.0001) and taking part in leisure activities (B = 1.58, p = 0.005) were independently associated with higher tongue pressure, but there was no link with social networks beyond neighbors (B = 0.23, p = 0.77). Sex-specific analyses showed that for men, having a partner was associated with higher tongue pressure, independent of the number of people in the household (B = 2.26, p = 0.01), but there was no association among women (B = −0.24, p = 0.72; p-interaction = 0.059).

Conclusions

Having a social network involving neighbors and taking part in leisure activities were independently associated with higher tongue pressure. Marital status may be an important factor in higher tongue pressure in men.

Keywords: Social network, Social environment, Oral frailty, Family arrangement, Marital status, Epidemiology

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Strengths and limitations of this study

- This is the first study of which we are aware to examine a possible association between tongue pressure and social environment among population-based samples.
- Social environment was measured using a unique approach, focusing on family structure, social networks both with neighbors and beyond, and leisure activities, using simple questions.
- Detailed information about social networks and leisure activities, including quality and quantity of social networks, or type of activities, was not available.
- Social environment data were self-reported, and may therefore reflect a point in time, rather than a long-term situation.
- Causal relationships cannot be inferred because of the cross-sectional design.

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INTRODUCTION

The proportion of people aged 60 years or over is expected to rise from 12% to 22% of the total global population between 2015 and 2050.[1] In Japan, it was already 33% in 2015 and is still rising.[2] Pneumonia is the third most common cause of death in Japan,[2] and often results in reduced quality of life for both pneumonia patients and their families, as well as high medical costs.[2][3] The vast majority (97%) of pneumonia deaths in Japan in 2015 were among those aged 65 years or over,[2] and most cases hospitalized for pneumonia were aspiration pneumonia.[4] Dysphagia is a main cause of aspiration,[5] and a susceptible condition for development of pneumonia in older people. A recent systematic review of high quality studies reported that estimated mean prevalence of dysphasia among community dwelling older people is 15%.[6] Dysphagia and related aspiration pneumonia prevention for both older people and younger populations is therefore a public health priority in Japan and is expected to be an important issue in other countries.

Social environment refers to the immediate physical surroundings, social relationships, and cultural milieus within which defined groups of people function and interact,[7] and which has a strong influence on physical and psychological health.[8] 'Social network' is part of the social environment, covering the structure of relationships, both quality and quantity,[9,10] including family relationships. For example, family members could have a strong influence on health[11] through lifestyle factors such as diet, economic situation, living environment, behavior, or emotions. Having a small social network has been linked to higher risk of mortality[12,13] and incidence of cardiovascular diseases (coronary heart disease,[12,14] heart failure,[15] and stroke[10,13]). Having fewer social interactions may be associated with earlier onset of physical and/or cognitive functional disability.[16] Although some population-based studies have suggested that social relationships were associated with oral health, including number of teeth remaining, tooth decay and periodontitis,[17][18] evidence of their effect on tongue pressure is sparse. Tongue pressure is essential to mix food and saliva into a bolus and pass it to the pharynx, which is an important phase in the feeding and swallowing process.[19][20] The tongue also has important functions in daily activities and communications because tongue movement controls articulation and pronunciation.[21]

Lower oral function is related to dysphagia and subsequent aspiration pneumonia.[22] Risk factors for dysphagia include age, existence of lung diseases, stroke,[23], dementia, Parkinson's disease, low tongue pressure, tooth loss, diabetes, or xerostomia,[24] use of hypertension medication, antipsychotic drugs, and

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malnutrition.[6] Bad oral health and poor oral hygiene have been linked to the development of aspiration pneumonia,[24][25] and oral care has been reported as a preventive factor.[25]

Previous experimental studies have shown that lingual exercise[26] had a positive influence on tongue function assessed by isometric and swallowing pressures, and lingual volume. No study, however, has examined whether social environment and daily activities are associated with tongue pressure as a potential risk factor for dysphagia and aspiration. Dysphagia and risk of aspiration can be evaluated in a hospital, measuring swallowing function by videofluoroscopic examination and videoendoscopic evaluation of swallowing, but these techniques are not useful for screening in a community. Tongue-pressure measurement has recently been identified as a useful proxy for risk of aspiration,[27][28] as it assesses tongue motor function. Good reproducibility and high correlations of this measurement with other objective measurements for oral function (e.g., the repetitive saliva swallowing test, speech intelligibility test, oral diadochokinesis and capacity of tongue-holding and movement test)[21] and symptoms of dysphagia[28] have been reported.

We hypothesized that social environment and daily activities may influence tongue pressure, because having social networks and taking part in leisure activities may increase opportunities to move the tongue. We also hypothesized that there may be sex differences in those associations because of possible biological sex differences[29] and cultural gender roles in Japan, where men work outside the home, and women tend to be more involved in household chores.[30] In such a culture, social environments could differ by sex. Using data from the Nagasaki Islands Study, we tested the hypotheses that people's social environment, including their family structure, social networks with and beyond their neighbors, and participation in leisure activities would be positively associated with higher tongue pressure, independent of physical, psychological, and behavioral risk factors for dysphagia.

METHODS

Study sample

The Goto City municipal government provides annual health check-ups for all residents aged 40 years or older. These check-ups take place in community centers within walking distance of each person's home. The Nagasaki Islands Study collaborated with the local government to conduct research, mainly targeting atherosclerosis diseases and frailty, by providing additional examinations.[6] In this study, every family unit in

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Tamanoura and Naru districts in 2015, and Tomie, Kishuku, Miiraku and Hisaka districts in 2016 was informed about the additional examinations by flyers before the study (N = 11741). All 2103 residents who attended the annual health check-ups received an initial invitation to participate in the Nagasaki Islands Study (response rate = 17.9%). Of the 2103 participants, 1982 (821 men and 1161 women) participated in this study (agreement rate = 94.2 %). The Nagasaki Islands study included maximum tongue pressure measurements. For this cross-sectional analysis, we excluded participants without data on tongue pressure (N = 14), resulting in a final sample for analysis of 815 men and 1153 women (**Supplemental Figure 1**). This study was approved by the Ethics Committee in Nagasaki University Graduate School of Biomedical Sciences (project registration number: 14051404), and all participants gave informed consent.

Measures

Tongue Pressure Measurement

The Tongue Pressure Measurement Device (JMS Co., Ltd., TPM-01) was used during health check-ups to evaluate a part of qualitative oral function by measuring maximum tongue pressure. The TPM-01 is a newly developed handheld manometry device, using a small balloon-type disposable oral probe with a plastic pipe, which is placed on the upper surface of the tongue. The TPM-01 is approved as the first medical device for tongue pressure measurement in Japan in 2010.[21] The measurements by the device were closely equivalent to those of the other widely-used tongue pressure manometers, the Iowa Oral Performance Instrument (IOPI), and the stable adhered three air-filled bulbs manometry system of the KayPENTAX Digital Swallowing Workstation™.[31] As a zero calibration, the probe was inflated with air at a pressure of 19.6 kPa.[31] Measurement was performed in a relaxed sitting position, and participants were asked to compress the small balloon to the palate as hard as they could, using their tongue. The maximum value was recorded automatically and displayed on the device.[31] The measurement was performed three times, and the maximum tongue pressure was used for analysis.

Social environment assessment

Social environment was assessed using a questionnaire about participants' social networks and daily activities. We asked about participants' family household structure, social networks with their neighbors and beyond, and participation in leisure activities. Family household structure was assessed by number of family members in the

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household, and marital status. Participants were asked whether they were married, divorced, separated, or unmarried, and responses were classified dichotomously as married (having a partner) or not. Social networks were assessed by asking "Do you have any close neighbors with whom you can talk?" (social network involving neighbors), and "Do you have any close friends, family or relatives beyond your neighbors whom you visit and who visit you?" (social network beyond neighbors). Leisure activities were assessed by asking "Do you have any hobbies, interests, or leisure activities inside or outside your home?". Choices for those questions were yes or no. Those three questions about social networks and leisure activities are part of the Frailty Index for Japanese older people.[32]

Measurement of covariates

Questionnaires were used to obtain information on age, sex, smoking status (current, former, or never), alcohol use (current, former, or never), physical exercise, psychological distress, medical history and medication use. Physical activity was assessed by asking "Have you been in the habit of doing exercise that makes you sweat lightly for over 30 minutes a time, at least twice weekly, for over a year?" and "In your daily life, do you walk or do an equivalent amount of physical activity for more than one hour a day?" The choices were yes or no. Participants who answered no for both questions were considered to be physically inactive, and those who answered yes for either as physically active.

Psychological distress was measured using the Japanese version of the Kessler 6 (K6) scale, a quantifier of non-specific psychological distress.[33] Physiological variables were measured by trained technicians. Weight (kg) and height (cm) were measured in light clothes (DC-250; Tanita, Tokyo, Japan). Resting blood pressure was measured using digital devices (HEM-907; Omron, Kyoto, Japan). Hypertension was defined as diastolic blood pressure ≥ 90 mmHg, systolic blood pressure ≥ 140 mmHg, and/or self-reported antihypertensive medication use. Diabetes mellitus was defined as hemoglobin A1c ≥ 6.5%, or use of medication for diabetes. History of stroke and respiratory disease were identified by self-reported medication use or having accessed medical care for those diseases. All measurements are routinely provided for all participants.

Statistical analysis

Descriptive statistics of covariates and potential mediators, by participants' sex, were generated using Student's *t*-tests and χ^2 tests. To see sex and age-specific distribution of

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maximum tongue strength and oral frailty, the proportions of each age group (40–49, 50–59, 60–69, 70–79, and 80 years or over) in each maximum tongue pressure band (<19.9 kPa, 20.0–29.9 kPa, 30.0–39.9 kPa, and ≥ 40 kPa) were calculated. There is no validated cut-off point for maximum tongue pressure indicating oral frailty.[27][20] Association between marital status and number of family members in the household was assessed by Wilcoxon rank-sum test. We used χ^2 tests to examine whether there were links between marital status, social networks and leisure activity. Multiple linear regression analysis was used to calculate total and sex-specific parameter estimates (B) for maximum tongue pressure after sequential adjustment for potential confounding variables. We used four sequential models. Model 1 adjusted for age and sex, Model 2 also adjusted for body mass index, lifestyle factors (smoking status, alcohol drinking status, and physical activity), psychological distress (K6 score) and major risk factors for dysphagia (anti-hypertensive medicine use, diabetes, and history of stroke and respiratory disease). The number of family members in the household, marital status, social networks with and beyond neighbors, and participation in leisure activities were included in the models. As marital status may be related to number of family members, we also included number of family members in the household (Model 3) and marital status (Model 4) separately to avoid over-adjustment.

In sensitivity analyses, we excluded participants with a history of stroke or respiratory disease, to avoid the possibility that lower tongue pressure or overall oral function was an after-effect of those diseases. We also examined the sex-specific associations, and tested whether sex modified the relationships of social networks and leisure activities with maximum tongue pressure, by including cross-product terms in the models (Model 2). All analyses used SAS 9.4 (SAS Institute Inc.).

RESULTS

The 1968 participants in our final sample for analysis were on average 70.6 years old (range 40 to 95), 59% female, and with a mean BMI of 23.4 kg/m^2. **Table 1** shows the characteristics of participants by sex. The mean (standard deviation, SD) maximum tongue pressure was 32.4 (10.4) kPa in men and 29.8 (9.6) kPa in women (p for difference < 0.0001). The tongue pressure was lower among older age groups in both men and women (**Figure 1**). A total of 93 (11.4%) men were classified as having a tongue pressure < 19.9 kPa, 227 (27.9%) as 20.0 to 29.9 kPa, and 495 (60.7%) as ≥30 kPa. In women, the figures were 171 (14.8%), 384 (33.3%) and 598 (51.9%). The mean number of family members in the household was greater for men (2.2 people) than

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women (2.0 people) (p = 0.001). The proportion of men having a partner was also higher (77% vs 63%) (p < 0.0001).

Table 1. Participant characteristics by sex: The Nagasaki Islands Study 2015–2016.

Sex Category	**Women**	**Men**	p for difference
N	1153	815	
Demographics			
Age, years[a]	70.4±9.3	70.1±10.3	0.44
Lifestyle Factors			
Physical Inactivity, N (%)	162 (14.1)	146 (17.9)	0.02
Cigarette Smoking Status, N (%)			
Never	1084 (94.0)	220 (27.0)	
Former	44 (3.8)	167 (52.5)	<.0001
Current	25 (2.2)	428 (20.5)	
Alcohol Drinking Status, N (%)			
Never	910 (78.9)	230 (28.2)	
Former	29 (2.5)	93 (11.4)	<.0001
Current	214 (18.6)	492 (60.4)	
Physiologic Characteristics			
Maximum Tongue Pressure			
Average, kPa[a]	29.8±9.6	32.4±10.4	<.0001
<20.0 kPa, N (%)	171 (14.8)	93 (11.4)	
20 to 29.9 kPa, N (%)	384 (33.3)	227 (27.9)	<.0001
30 to 29.9 kPa, N (%)	452 (39.2)	300 (36.8)	
≥40.0 kPa, N (%)	146 (12.7)	195 (23.9)	
Body Mass Index, kg/m^2 [a]	23.2±3.5	23.8±3.0	<.0001
Hypertension Medication, N (%)	540 (46.8)	393 (48.2)	0.54
Prevalent Diabetes, N (%) [b]	121 (10.5)	117 (14.4)	0.01
History of Stroke, N (%)	30 (2.6)	39 (4.8)	0.01
History of Respiratory Disease, N (%)	30 (2.6)	25 (3.1)	0.54
Psychologic Characteristics			
Psychological distress (K6 score)[a]	1.4±2.7	1.1±2.5	0.01

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Social Environments			
Number of family members in the household [a]	2.0±1.0	2.2±0.8	0.001
Marital Status (having a partner), N (%)	726 (63.0)	629 (77.2)	<.0001
Participation in leisure activities, N (%)	945 (82.0)	661 (81.2)	0.67
Having a Social network with neighbors, N (%)	1001 (86.8)	660 (81.0)	0.0004
Having a Social network beyond neighbors, N (%)	1062 (92.1)	724 (88.8)	0.01

[a] Represented as mean±SD)

[b] Diabetes was defined as hemoglobin A1c ≥6.5%, or medication use for diabetes.

Social Environment and Maximum Tongue Pressure among Participants

Multivariable adjusted linear regression analysis showed that having a social network involving neighbors and participation in leisure activities were positively associated with higher tongue pressure. The multivariable adjusted parameter estimates (B) were 2.43 ($p = 0.0001$) and 1.58 ($p = 0.005$) (**Table 2**, Model 2). The number of family members in the household, marital status and having a social network beyond neighbors were not associated with maximum tongue pressure. The associations did not change when we included number of family members in the household (Model 3) and marital status (Model 4) separately.

Using Wilcoxon rank-sum test, the number of family members in the household was larger for participants with a partner than those without ($p < 0.0001$). The average number of family members living in the household was 2.08±0.93, and 87% of participants who were living with someone were married. Using χ^2 tests, marital status (having a partner) was associated with taking part in leisure activities and having social networks with/beyond neighbors in men (all $p < 0.0001$), but not in women. Having social networks with neighbors was associated with taking part in leisure activities and having social networks beyond neighbors in both men and women. Having social networks with/beyond neighbors was also associated with taking part in leisure activities in both sexes.

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Table 2. Association of Social Environment with Maximum Tongue Pressure: The Nagasaki Islands Study 2015–2016.

Social Environments	Model 1[a]				Model 2[b]				Model 3[c]				Model 4[c]			
	B	95 % CI	p value	R^2	B	95 % CI	p value	R^2	B	95 % CI	p value	R^2	B	95 % CI	p value	R^2
TOTAL																
Number of family members in the household	-0.45	(-0.97, 0.07)	0.09		-0.44	(-0.95, 0.07)	0.09		-0.32	(-0.78, 0.15)	0.18		-	-	-	
Marital Status	0.49	(-0.52, 1.50)	0.34		0.59	(-0.42, 1.59)	0.25		-	-	-		0.3	(-0.62, 1.21)	0.53	
Participation in leisure activities	**1.9**	**(0.78, 3.01)**	**0.001**	0.12	**1.58**	**(0.48, 2.68)**	**0.005**	0.16	**1.6**	**(0.51, 2.70)**	**0.004**	0.16	**1.61**	**(0.52, 2.71)**	**0.004**	0.16
Social network with neighbors	**2.6**	**(1.35, 3.85)**	**<.0001**		**2.43**	**(1.19, 3.67)**	**0.0001**		**2.41**	**(1.18, 3.65)**	**0.0001**		**2.37**	**(1.14, 3.60)**	**0.0002**	
Social network beyond neighbors	0.55	(-1.01, 2.11)	0.49		0.23	(-1.30, 1.77)	0.77		0.32	(-1.21, 1.85)	0.68		0.36	(-1.17, 1.88)	0.64	
Women																
Number of family members in the household	-0.13	(-0.77, 0.51)	0.69		-0.18	(-0.82, 0.46)	0.58		-0.23	(-0.81, 0.35)	0.44		-	-	-	
Marital Status	-0.34	(-1.62, 0.93)	0.6	0.08	-0.24	(-1.51, 1.04)	0.72	0.11	-	-	-	0.11	-0.3	(-1.47, 0.86)	0.61	0.11
Participation in leisure activities	**1.61**	**(0.18, 3.03)**	**0.03**		1.42	(-0.01, 2.84)	0.05		1.41	(-0.01, 2.83)	0.05		1.41	(-0.02, 2.83)	0.05	

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Social network with neighbors	**2.73**	**(1.07, 4.39)**	**0.001**		**2.67**	**(1.00, 4.33)**	**0.002**		**2.68**	**(1.01, 4.34)**	**0.002**		**2.63**	**(0.97, 4.29)**	**0.002**	
Social network beyond neighbors	1.15	(-0.93, 3.23)	0.28		1.17	(-0.90, 3.23)	0.27		1.13	(-0.92, 3.19)	0.28		1.23	(-0.82, 3.27)	0.24	
Men																
Number of family members in the household	**-1.03**	**(-1.92, -0.14)**	**0.02**		-0.81	(-1.68, 0.07)	0.07		-0.37	(-1.17, 0.44)	0.37		-	-	-	
Marital Status	**2.65**	**(0.85, 4.45)**	**0.004**		**2.26**	**(0.47, 4.04)**	**0.01**		-	-	-		1.61	(-0.02, 3.23)	0.05	
Participation in leisure activities	**2.12**	**(0.35, 3.90)**	**0.02**	0.14	1.73	(-0.02, 3.48)	0.05	0.18	**1.9**	**(0.15, 3.65)**	**0.03**	0.18	**1.89**	**(0.15, 3.63)**	**0.03**	0.18
Social network with neighbors	**2.43**	**(0.51, 4.34)**	**0.01**		**2.13**	**(0.25, 4.02)**	**0.03**		**2.14**	**(0.25, 4.03)**	**0.03**		**2.04**	**(0.15, 3.92)**	**0.03**	
Social network beyond neighbors	-0.26	(-2.66, 2.14)	0.83		-1.02	(-3.39, 1.35)	0.4		-0.74	(-3.11, 1.63)	0.54		-0.96	(-3.32, 1.40)	0.43	

The number of family members in the household, marital status, social networks with and beyond neighbors, and participation in leisure activities were included in Models 1–4.

[a] Model 1: Adjusted for age and sex.

[b] Model 2: Adjusted for Model 1 + lifestyle factors (physical activity, smoking status, drinking status) + physiological characteristics (body mass index) + psychological distress (K6 score) + major dysphagia risk factors (anti-hypertensive medicine use, diabetes, history of stroke, respiratory disease)

[c] Models 3–4: Adjusted for the same variables in Model 2 other than number of family members in the household and marital status, which were separately included in Models 3 and 4 to avoid over-adjustment.

B = parameter estimate.

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Sex-Specific Association in Social Environment and Maximum Tongue Pressure

In the sex-specific multivariable adjusted linear regression analyses, the associations between maximum tongue pressure and either social networks involving neighbors or participation in leisure activities were similar to the combined figures for women and men. The multivariable adjusted B-values were 2.67 (p = 0.002) and 1.42 (p = 0.05) for women, and 2.13 (p = 0.03) and 1.73 (p = 0.05) for men (**Table 2**, Model 2). Having social networks beyond neighbors was not associated with tongue pressure at all, whereas number of family members in the household tended to be negatively associated (B = −0.81, p = 0.07), and marital status (having a partner) was significantly positively associated with higher tongue pressure in men (B = 2.26, p = 0.01), but not women (B = −0.18, p = 0.58, and B = −0.24, p = 0.72). When we separately included number of family members in the household (Model 3) and marital status (Model 4), the associations were attenuated in men, but the attenuation did not alter the relationships of social networks and participation in leisure activities with tongue pressure.

In sensitivity analyses excluding participants with stroke or respiratory disease to exclude influences on tongue pressure or overall oral function from those diseases or associated medication, neither the overall nor sex-specific results changed (**Supplemental Table 1**). There was no evidence that sex modified the relationship of number of family members in the household, networks with and beyond neighbors and leisure activities with maximum tongue pressure (interaction p = 0.87, p = 0.36, p = 0.19, p = 1.00). It did, however, show a borderline significant interaction in the association between marital status and maximum tongue pressure (interaction p = 0.059).

DISCUSSION

In this population-based study of 1968 participants, having a social network involving neighbors and participating in leisure activities were associated with higher maximum tongue pressure. This association was independent of age, sex, body mass index, psychological distress, behavioral factors, and other risk factors for dysphagia. Having a partner was associated with greater tongue pressure in men only. This is the first evidence of which we are aware that suggests that social environment may influence tongue pressure. It supports previous reports suggesting the importance of social ties and taking part in daily leisure activities in improving or maintaining tongue function and possible prevention of dysphagia and aspiration.

Our results are consistent with previous studies on daily and social activities, in

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which oral function was assessed by self-reported questionnaire.[34][42] Kamakura et al carried out a questionnaire survey among 769 local senior club members, and reported that factors related to daily activities such as time spent outside the home each day, higher frequency of loud laughing, and enjoying eating were associated with a lower proportion of swallowing problems (self-reported choking on food).[34] A previous community-based study of 1405 randomly selected older people showed that not participating in social activities was linked to a self-assessed masticatory problem.[35]

Although the mechanisms underlying the association between social networks or participation in leisure activities and tongue pressure have not been fully elucidated, physiological, behavioral, and psychological factors are likely to be involved. Higher activity in muscles around the pharynx and mouth may have a positive effect on tongue function. People who are living with family members and have close neighbors may communicate with others more often, and particularly have more opportunity to eat together, have conversations and laugh. Eating with someone could have a positive influence on oral function via increased saliva production and higher tongue activity, as well as having a preventive effect on depression.[36] It may also be related to better nutrition, eating behavior, dietary composition and energy levels,[37] as well as more social interactions.[38] A link was identified between laughter and enjoying eating and lower self-reported symptoms of aspiration in an epidemiological study.[34]

The difference in frequency of social interactions in daily life could explain why only social networks involving neighbors, and not those beyond, were associated with higher tongue pressure in this study. The influence of social networks beyond neighbors on tongue pressure could depend on both the type of relationship (close family, wider relatives, or friends) and frequency of meeting, but the results suggest a possibility that an effective public health intervention to prevent oral frailty and subsequent aspiration might focus on social networks involving neighbors. Hikichi et al. reported that community intervention may be effective in encouraging social participation among Japanese older people, and helping to prevent the onset of functional disability.[16] That study confirmed that the number of community-based centers for older people, so-called ‘community salons’, within 350 meters of the home was related to frequency of participation. It also found that incidence of functional disability among residents who participated in ‘community salons’ three or more times over the 4.9 years of follow-up was reduced by 50% over those who participated twice or less. The result was similar even when the researchers accounted for the possibility of selection bias by using propensity score matching analysis and instrumental variable

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analysis.[16]

The number of family members in the household was not associated with tongue pressure in the combined analysis, and a negative association was observed in men. We think this may be partially because of possible differences in duration of living with family members. There is also a possibility of reverse causation: some people may have started to live with family members as a result of decreased ability to perform activities of daily living. We did not collect any detailed information about leisure activities, but these could be related to higher social interaction, physical/mental activity, self-actualization or 'Ikigai', a comprehensive Japanese concept encompassing the 'meaning of life' and/or 'purpose in life'.[39] Large population-based longitudinal studies of older people in Japan have reported that having hobbies or social participation may be effective in decreasing the risk of functional disability,[40] and progression of senility associated with dementia.[41] A previous report from the Japanese government showed that people with more friends had a stronger feeling of 'Ikigai'.[42] The proportion participating in leisure activities was higher in participants with social networks both with and beyond neighbors in our study, but we believe the associations with higher tongue pressure are likely to be independent. The reason for the sex difference in the association between marital status and tongue pressure is unknown, but cultural gender roles in Japan and health-related behaviors could partially mediate the association. As men more often work outside the home, and women are more involved in household chores in Japan,[30] women may have more opportunity to communicate with their neighbors than men, regardless of marital status. Our results suggested that the proportion having social networks and participating in leisure activities were lower among married men than unmarried. Health-compromising behaviors (e.g., smoking, heavy drinking, lower vegetable consumption and less frequent dental visits) have previously been shown to be related to marital status in both men[43,44] and women.[44,45] Marital termination (e.g., divorce and widowhood) were associated with an elevated mortality risk for men, but not for women in a large Japanese cohort study.[46]

The association between tongue pressure and both social networks and participation in leisure activities were independent of psychological distress in this study. Psychological distress could influence oral function via lower frequency and number of communications, related to reduced social interaction,[47] as well as altered health-promoting behaviors (e.g., brushing teeth, consuming a healthy diet, exercising, not smoking). Medication use for depression is also known to be a risk factor for dysphagia and aspiration because of the muscle relaxant effect. A future study

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examining links with medication use for depression may be helpful.

Strengths and Limitations

Our study had several limitations. Social networks and participation in leisure activities were assessed using a dichotomous answer, so detailed information about the social network quality (e.g., relationship or closeness) and quantity (e.g., number involved in the social network, and frequency of communications), or the type of activity (e.g., solo or social activity) were not available in this study. However, the simplicity of the question is useful in identifying people with at least one social network or leisure activity. Further studies will be needed to investigate the influence of various detailed aspects of social networks and leisure activities on tongue pressure. Second, measurement error and subsequent misclassification almost certainly occurred, because the social environment data were self-reported. Participants' answers were about their mental and social environment at the point of response, and further studies will therefore be needed to assess the duration of the situation (e.g., how long they have been living alone) and timing (e.g., when they lost their partner, or retired). Age-stratified analysis will be needed Third, tongue-pressure measurement has good reproducibility and high correlations with other objective measurements for oral functions,[21] but unmeasured characteristics of the participants like cognitive decline, or oral conditions like denture use could have influenced the measurement. Fourth, although we adjusted for potential confounders including disease-related dysphagia risk (stroke, and respiratory disease), there may have been other residual or unmeasured confounders (for example, other diseases like dementia, epilepsy, medication use including anticholinergics, diuretics, antidepressant or sleep medicine, and diet and lifestyle changes) that influenced the association between social environment and tongue pressure. Fifth, causal relationships cannot be identified from cross-sectional analyses. There is a possibility of reverse causation or bi-directional relationships.[48] For example, people without oral frailty may maintain larger social networks or participate in more daily activities, or some people could have started to live with family members as a result of weakened physical function, but this cannot be assessed. Sixth, the study response rate was under 20% in the target population in the city, which may have led to population bias. However, we believe that the high rate of agreement to participate (94%) is likely to have minimized any bias among the population. Seventh, although age-related social environment differences and/or tongue pressure (Figure 1) may have influenced the associations, we could not assess the most appropriate age cut-off point for the associations, partly because we have limited population data to explore this.

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Further research with a larger sample sizes or prospective design would be needed to investigate whether there are age-specific associations. Last, our study subjects were from a rural area in Japan, in which social ties with neighbors could be stronger than those in urban areas. Further research would be needed to assess the generalizability of the study.

The strengths of our study included objective measurement of tongue pressure using population-based samples, a comprehensive assessment of social environment focusing on family structure, social networks within and beyond neighbors, and participation in leisure activities, and standardized data collection for potential risk factors for dysphagia including psychological distress, and physical and behavioral characteristics.

CONCLUSIONS

Having a social network involving neighbors and taking part in leisure activities were independently associated with higher maximum tongue pressure in a sample of community-dwelling men and women. Marital status may be also an important factor in maintaining tongue pressure among men. Further studies will be needed to assess the impact of particular elements of the social environment on tongue pressure, including social network size, quality and duration of the situation, or type of activities, using a prospective design. This study, however, suggests the importance of family structure including marital status, social networks with and beyond neighbors, and participation in leisure activities for risk assessment of oral frailty.

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Competing interests

All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

Authors' contributions

MN conceived the study, analyzed and interpreted the data, drafted the manuscript, and provided statistical expertise. MN, MH, NT, MT, JK, HY, KK, SS, ZK, TS, TM acquired the data. MN, MH, NT, MT, JK, HY, KK, SS, SK, ZK, TS, TM interpreted the data and critically revised the manuscript. TM is guarantor for the study. All authors approved the final version of the paper.

Data sharing statement: No additional data are available.

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Figure 1. Sex-specific maximum tongue pressure by age group: The Nagasaki Islands Study 2015–2016.

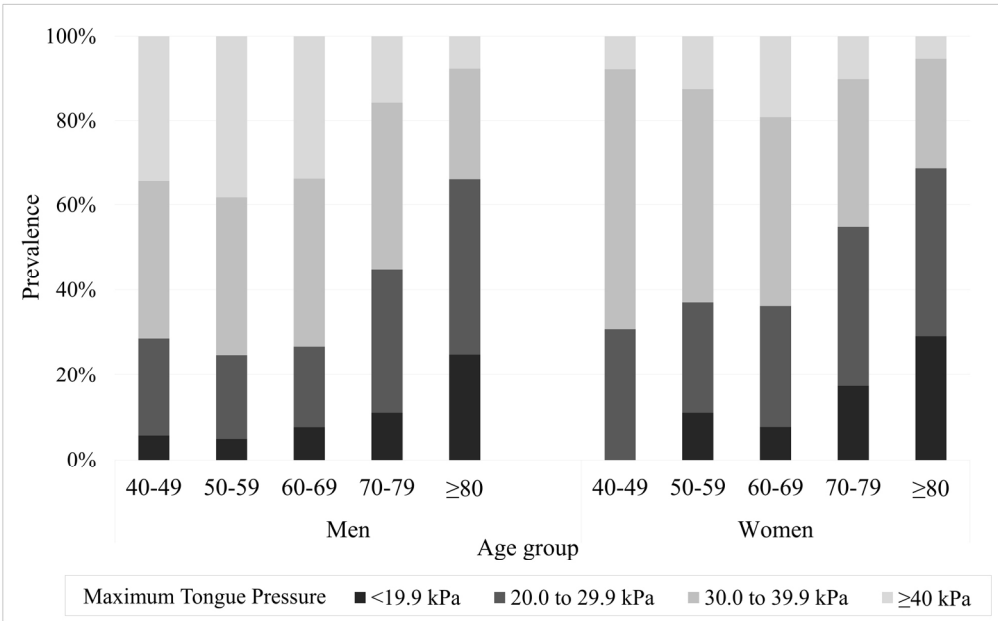

Figure 1. Sex-specific maximum tongue pressure by age group: The Nagasaki Islands Study 2015–2016.

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Social Networks, Leisure activities and Oral Frailty: Cross-sectional Association in The Nagasaki Islands Study

Mako Nagayoshi, Miho Higashi, Noboru Takamura, Mami Tamai, Jun Koyamatsu, Hirotomo Yamanashi, Koichiro Kadota, Shimpei Sato, Shin-ya Kawashiri, Zenya Koyama, Toshiyuki Saito, Takahiro Maeda

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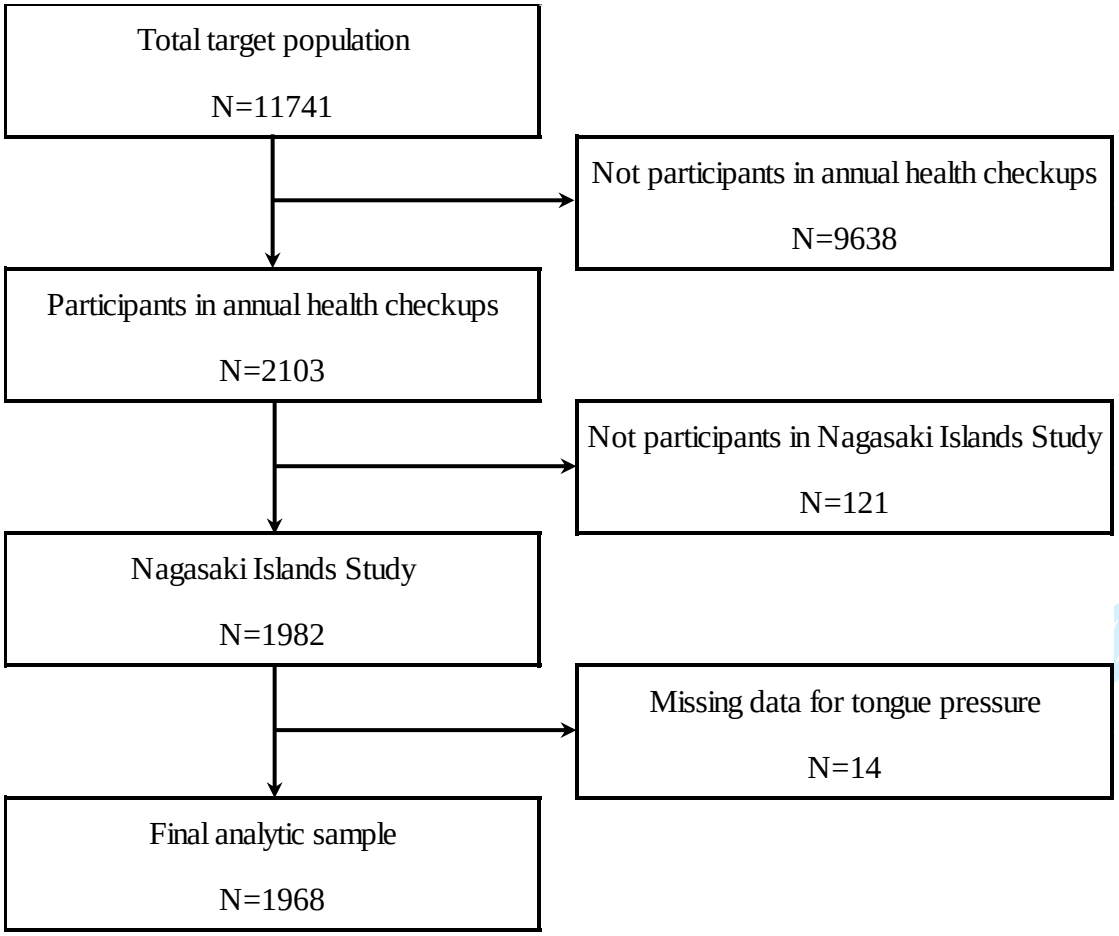

Supplemental Figure 1. Study sample flow chart.

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Supplemental Table 1. Association of Social Environments with Maximum Tongue Pressure among Participants without History of Stroke or Respiratory Disease: The Nagasaki Islands Study 2015–2016.

	Model 1[a]				Model 2[b]				Model 3[c]				Model 4[c]			
Social Environments	B	95 % CI	p value	R^2	B	95 % CI	p value	R^2	B	95 % CI	p value	R^2	B	95 % CI	p value	R^2
TOTAL																
Number of family members in the household	**-0.62**	**(-1.18, -0.06)**	**0.03**		**-0.65**	**(-1.20, -0.10)**	**0.02**		**-0.50**	**(-1.00, 0.00)**	**0.05**					
Marital Status	0.56	(-0.50, 1.61)	0.30		0.65	(-0.40, 1.70)	0.22						0.19	(-0.76, 1.13)	0.70	
Participation in leisure activities	**1.99**	**(0.84, 3.14)**	**0.001**	0.11	**1.67**	**(0.54, 2.81)**	**0.004**	0.16	**1.71**	**(0.57, 2.84)**	**0.003**	0.16	**1.73**	**(0.60, 2.86)**	**0.003**	0.15
Social network with neighbors	**2.65**	**(1.37, 3.94)**	**<.0001**		**2.45**	**(1.17, 3.72)**	**0.0002**		**2.43**	**(1.16, 3.71)**	**0.0002**		**2.36**	**(1.09, 3.64)**	**0.0003**	
Social network beyond neighbors	0.46	(-1.15, 2.08)	0.57		0.12	(-1.46, 1.71)	0.88		0.21	(-1.37, 1.79)	0.79		0.26	(-1.32, 1.84)	0.75	
Women																
Number of family members in the household	-0.25	(-0.95, 0.46)	0.49		-0.38	(-1.08, 0.32)	0.29		-0.45	(-1.08, 0.18)	0.16					
Marital Status	-0.48	(-1.82, 0.86)	0.48		-0.29	(-1.63, 1.05)	0.67						-0.54	(-1.75, 0.66)	0.38	
Participation in leisure activities	**1.63**	**(0.15, 3.10)**	**0.03**	0.07	1.44	(-0.04, 2.91)	0.06	0.11	1.43	(-0.05, 2.90)	0.06	0.11	1.42	(-0.05, 2.90)	0.06	0.11
Social network with neighbors	**2.84**	**(1.13, 4.54)**	**0.001**		**2.69**	**(0.98, 4.40)**	**0.002**		**2.69**	**(0.98, 4.40)**	**0.002**		**2.62**	**(0.91, 4.33)**	**0.003**	
Social network beyond neighbors	1.27	(-0.88, 3.41)	0.25		1.37	(-0.75, 3.50)	0.21		1.34	(-0.78, 3.46)	0.22		1.45	(-0.67, 3.57)	0.18	
Men																

Number of family members in the household	**-1.22**	**(-2.14, -0.30)**	**0.01**		**-1.00**	**(-1.90, -0.10)**	**0.03**		-0.50	(-1.33, 0.34)	0.24				
Marital Status	**3.08**	**(1.22, 4.95)**	**0.001**		**2.59**	**(0.74, 4.43)**	**0.006**						**1.79**	**(0.10, 3.48)**	**0.04**	
Participation in leisure activities	**2.36**	**(0.52, 4.20)**	**0.01**	0.14	**1.96**	**(0.16, 3.77)**	**0.03**	0.18	**2.16**	**(0.35, 3.97)**	**0.02**	0.17	**2.15**	**(0.35, 3.95)**	**0.02**	0.18
Social network with neighbors	**2.55**	**(0.58, 4.52)**	**0.01**		**2.19**	**(0.25, 4.12)**	**0.03**		**2.15**	**(0.21, 4.09)**	**0.03**		**2.04**	**(0.11, 3.98)**	**0.04**	
Social network beyond neighbors	-0.75	(-3.24, 1.74)	0.55		-1.65	(-4.11, 0.81)	0.19		-1.27	(-3.73, 1.18)	0.31		-1.54	(-3.99, 0.92)	0.22	

The number of family members in the household, marital status, social networks with and beyond neighbors, and participation in leisure activities were included in Models 1–4.

[a] Model 1: Adjusted for age and sex.

[b] Model 2: Adjusted for Model 1 + lifestyle factors (physical activity, smoking status, drinking status) + physiological characteristics (body mass index) + psychological distress (K6 score) + major dysphagia risk factors (anti-hypertensive medicine use, diabetes, history of stroke, respiratory disease)

[c] Models 3–4: Adjusted for the same variables in Model 2 other than number of family members in the household and marital status, which were separately included in the Models 3 and 4 to avoid over-adjustment.

B = parameter estimate.

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STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1, 2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-8
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	N/A
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	N/A
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5-8
Bias	9	Describe any efforts to address potential sources of bias	7-8, 16-17
Study size	10	Explain how the study size was arrived at	5-6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7-8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7-8
		(*b*) Describe any methods used to examine subgroups and interactions	7-8
		(*c*) Explain how missing data were addressed	6
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	5-6, Supplemental Figure 1
		(*e*) Describe any sensitivity analyses	8

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Results			Page #
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	5-6, Supplemental Figure 1
		(b) Give reasons for non-participation at each stage	5-6
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exosures and potential confounders	8-11, Table 1, Figure 1
		(b) Indicate number of participants with missing data for each variable of interest	6
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	N/A
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	N/A
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	N/A
		Cross-sectional study—Report numbers of outcome events or summary measures	8-13, Table 1-2, Supplemental Table 1
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	8, Table 2, Supplemental Table 1
		(*b*) Report category boundaries when continuous variables were categorized	N/A
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	13, Supplemental Table 1
Discussion			
Key results	18	Summarise key results with reference to study objectives	13-17
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16-17
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13-17
Generalisability	21	Discuss the generalisability (external validity) of the study results	16-17
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article	17-18

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is based

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*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Social Networks, Leisure Activities and Maximum Tongue Pressure: Cross-sectional Associations in The Nagasaki Islands Study

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Manuscripts

Social Networks, Leisure Activities and Maximum Tongue Pressure: Cross-sectional Associations in The Nagasaki Islands Study

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ABSTRACT

Objectives

Social environment is often associated with health outcomes, but epidemiological evidence for its effect on oral frailty, a potential risk factor for aspiration, is sparse. This study aimed to assess the association between social environment and tongue pressure, as an important measure of oral function. The study focused on family structure, social networks both with and beyond neighbors, and participation in leisure activities.

Design

A population-based cross-sectional study.

Setting

Annual health check-ups in a rural community in Japan.

Participants

A total of 1982 participants, all over 40 years old. Anyone with missing data for the main outcome (N = 14) was excluded.

Outcome measures

Tongue pressure was measured three times, and the maximum tongue pressure was used for analysis. A multivariable adjusted regression model was used to calculate parameter estimates (B) for tongue pressure.

Results

Having a social network involving neighbors (B = 2.43, p = 0.0001) and taking part in leisure activities (B = 1.58, p = 0.005) were independently associated with higher tongue pressure, but there was no link with social networks beyond neighbors (B = 0.23, p = 0.77). Sex-specific analyses showed that for men, having a partner was associated with higher tongue pressure, independent of the number of people in the household (B = 2.26, p = 0.01), but there was no association among women (B = −0.24, p = 0.72; p-interaction = 0.059).

Conclusions

Having a social network involving neighbors and taking part in leisure activities were independently associated with higher tongue pressure. Marital status may be an important factor in higher tongue pressure in men.

Keywords: Social network, Social environment, Oral frailty, Family arrangement, Marital status, Epidemiology

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Strengths and limitations of this study

- This is the first study of which we are aware to examine a possible association between tongue pressure and social environment among population-based samples.
- Social environment was measured using a unique approach, focusing on family structure, social networks both with neighbors and beyond, and leisure activities, using simple questions.
- Detailed information about social networks and leisure activities, including quality and quantity of social networks, or type of activities, was not available.
- Social environment data were self-reported, and may therefore reflect a point in time, rather than a long-term situation.
- Causal relationships cannot be inferred because of the cross-sectional design.

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INTRODUCTION

The proportion of people aged 60 years or over is expected to rise from 12% to 22% of the total global population between 2015 and 2050.[1] In Japan, it was already 33% in 2015 and is still rising.[2] Pneumonia is the third most common cause of death in Japan,[2] and often results in reduced quality of life for both pneumonia patients and their families, as well as high medical costs.[2,3] The vast majority (97%) of pneumonia deaths in Japan in 2015 were among those aged 65 years or over,[2] and most cases hospitalized for pneumonia were aspiration pneumonia.[4] Dysphagia is a main cause of aspiration,[5] and a susceptible condition for development of pneumonia in older people. A recent systematic review of high quality studies reported that estimated mean prevalence of dysphasia among community dwelling older people is 15%.[6] Dysphagia and related aspiration pneumonia prevention for both older people and younger populations is therefore a public health priority in Japan and is expected to be an important issue in other countries.

Social environment refers to the immediate physical surroundings, social relationships, and cultural milieus within which defined groups of people function and interact,[7] and which has a strong influence on physical and psychological health.[8] 'Social network' is part of the social environment, covering the structure of relationships, both quality and quantity,[9,10] including family relationships. For example, family members could have a strong influence on health[11] through lifestyle factors such as diet, economic situation, living environment, behavior, or emotions. Having a small social network has been linked to higher risk of mortality[12,13] and incidence of cardiovascular diseases (coronary heart disease,[12,14] heart failure,[15] and stroke[10,13]). Having fewer social interactions may be associated with earlier onset of physical and/or cognitive functional disability.[16] Although some population-based studies have suggested that social relationships were associated with oral health, including number of teeth remaining, tooth decay and periodontitis,[17,18] evidence of their effect on tongue pressure is sparse. Tongue pressure is essential to mix food and saliva into a bolus and pass it to the pharynx, which is an important phase in the feeding and swallowing process.[19,20] The tongue also has important functions in daily activities and communications because tongue movement controls articulation and pronunciation.[21]

Lower oral function is related to dysphagia and subsequent aspiration pneumonia.[22] Risk factors for dysphagia include age, existence of lung diseases, stroke,[23], dementia, Parkinson's disease, low tongue pressure, tooth loss, diabetes, or xerostomia,[24] use of hypertension medication, antipsychotic drugs, and

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malnutrition.[6] Bad oral health and poor oral hygiene have been linked to the development of aspiration pneumonia,[24,25] and oral care has been reported as a preventive factor.[25]

Previous experimental studies have shown that lingual exercise[26] had a positive influence on tongue function assessed by isometric and swallowing pressures, and lingual volume. No study, however, has examined whether social environment and daily activities are associated with tongue pressure as a potential risk factor for dysphagia and aspiration. Dysphagia and risk of aspiration can be evaluated in a hospital, measuring swallowing function by videofluoroscopic examination and videoendoscopic evaluation of swallowing, but these techniques are not useful for screening in a community. Tongue-pressure measurement has recently been identified as a useful proxy for risk of aspiration,[27,28] as it assesses tongue motor function. Good reproducibility and high correlations of this measurement with other objective measurements for oral function (e.g., the repetitive saliva swallowing test, speech intelligibility test, oral diadochokinesis and capacity of tongue-holding and movement test)[21] and symptoms of dysphagia[28] have been reported.

We hypothesized that social environment and daily activities may influence tongue pressure, because having social networks and taking part in leisure activities may increase opportunities to move the tongue. We also hypothesized that there may be sex differences in those associations because of possible biological sex differences[29] and cultural gender roles in Japan, where men work outside the home, and women tend to be more involved in household chores.[30] In such a culture, social environments could differ by sex. Using data from the Nagasaki Islands Study, we tested the hypotheses that people's social environment, including their family structure, social networks with and beyond their neighbors, and participation in leisure activities would be positively associated with higher tongue pressure, independent of physical, psychological, and behavioral risk factors for dysphagia.

METHODS

Study sample

The Goto City municipal government provides annual health check-ups for all residents aged 40 years or older. These check-ups take place in community centers within walking distance of each person's home. The Nagasaki Islands Study collaborated with the local government to conduct research, mainly targeting atherosclerosis diseases and frailty, by providing additional examinations.[31] In this study, every family unit in

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Tamanoura and Naru districts in 2015, and Tomie, Kishuku, Miiraku and Hisaka districts in 2016 was informed about the additional examinations by flyers before the study (N = 11741). All 2103 residents who attended the annual health check-ups received an initial invitation to participate in the Nagasaki Islands Study (response rate = 17.9%). Of the 2103 participants, 1982 (821 men and 1161 women) participated in this study (agreement rate = 94.2 %). The Nagasaki Islands study included maximum tongue pressure measurements. For this cross-sectional analysis, we excluded participants without data on tongue pressure (N = 14), resulting in a final sample for analysis of 815 men and 1153 women (**Supplemental Figure 1**). This study was approved by the Ethics Committee in Nagasaki University Graduate School of Biomedical Sciences (project registration number: 14051404), and all participants gave informed consent.

Measures

Tongue Pressure Measurement

The Tongue Pressure Measurement Device (JMS Co., Ltd., TPM-01) was used during health check-ups to evaluate a part of qualitative oral function by measuring maximum tongue pressure. The TPM-01 is a newly developed handheld manometry device, using a small balloon-type disposable oral probe with a plastic pipe, which is placed on the upper surface of the tongue. The TPM-01 is approved as the first medical device for tongue pressure measurement in Japan in 2010.[21] The measurements by the device were closely equivalent to those of the other widely-used tongue pressure manometers, the Iowa Oral Performance Instrument (IOPI), and the stable adhered three air-filled bulbs manometry system of the KayPENTAX Digital Swallowing Workstation™.[32] As a zero calibration, the probe was inflated with air at a pressure of 19.6 kPa.[32] Measurement was performed in a relaxed sitting position, and participants were asked to compress the small balloon to the palate as hard as they could, using their tongue. The maximum value was recorded automatically and displayed on the device.[32] The measurement was performed three times, and the maximum tongue pressure was used for analysis.

Social environment assessment

Social environment was assessed using a questionnaire about participants' social networks and daily activities. We asked about participants' family household structure, social networks with their neighbors and beyond, and participation in leisure activities. Family household structure was assessed by number of family members in the

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household, and marital status. Participants were asked whether they were married, divorced, separated, or unmarried, and responses were classified dichotomously as married (having a partner) or not. Social networks were assessed by asking "Do you have any close neighbors with whom you can talk?" (social network involving neighbors), and "Do you have any close friends, family or relatives beyond your neighbors whom you visit and who visit you?" (social network beyond neighbors). Leisure activities were assessed by asking "Do you have any hobbies, interests, or leisure activities inside or outside your home?". Choices for those questions were yes or no. Those three questions about social networks and leisure activities are part of the Frailty Index for Japanese older people.[33]

Measurement of covariates

Questionnaires were used to obtain information on age, sex, smoking status (current, former, or never), alcohol use (current, former, or never), physical exercise, psychological distress, medical history and medication use. Physical activity was assessed by asking "Have you been in the habit of doing exercise that makes you sweat lightly for over 30 minutes a time, at least twice weekly, for over a year?" and "In your daily life, do you walk or do an equivalent amount of physical activity for more than one hour a day?" The choices were yes or no. Participants who answered no for both questions were considered to be physically inactive, and those who answered yes for either as physically active.

Psychological distress was measured using the Japanese version of the Kessler 6 (K6) scale, a quantifier of non-specific psychological distress.[34] Physiological variables were measured by trained technicians. Weight (kg) and height (cm) were measured in light clothes (DC-250; Tanita, Tokyo, Japan). Resting blood pressure was measured using digital devices (HEM-907; Omron, Kyoto, Japan). Hypertension was defined as diastolic blood pressure ≥ 90 mmHg, systolic blood pressure ≥ 140 mmHg, and/or self-reported antihypertensive medication use. Diabetes mellitus was defined as hemoglobin A1c ≥ 6.5%, or use of medication for diabetes. History of stroke and respiratory disease were identified by self-reported medication use or having accessed medical care for those diseases. All measurements are routinely provided for all participants.

Statistical analysis

Descriptive statistics of covariates and potential mediators, by participants' sex, were generated using Student's *t*-tests and χ^2 tests. To see sex and age-specific distribution of

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maximum tongue strength and oral frailty, the proportions of each age group (40–49, 50–59, 60–69, 70–79, and 80 years or over) in each maximum tongue pressure band (<19.9 kPa, 20.0–29.9 kPa, 30.0–39.9 kPa, and ≥ 40 kPa) were calculated. There is no validated cut-off point for maximum tongue pressure indicating oral frailty.[20,27] Association between marital status and number of family members in the household was assessed by Wilcoxon rank-sum test. We used χ^2 tests to examine whether there were links between marital status, social networks and leisure activity. Multiple linear regression analysis was used to calculate total and sex-specific parameter estimates (B) for maximum tongue pressure after sequential adjustment for potential confounding variables. We used four sequential models. Model 1 adjusted for age [continuous] and sex, Model 2 also adjusted for body mass index [continuous], lifestyle factors (smoking status [categorical], alcohol drinking status [categorical], and physical activity [dichotomous]), psychological distress (K6 score [continuous]) and major risk factors for dysphagia (anti-hypertensive medicine use, diabetes, and history of stroke and respiratory disease [all dichotomous]). The number of family members in the household, marital status, social networks with and beyond neighbors, and participation in leisure activities were included in the models. As marital status may be related to number of family members, we also included number of family members in the household (Model 3) and marital status (Model 4) separately to avoid over-adjustment.

In sensitivity analyses, we excluded participants with a history of stroke or respiratory disease, to avoid the possibility that lower tongue pressure or overall oral function was an after-effect of those diseases. We also examined the sex-specific associations, and tested whether sex modified the relationships of social networks and leisure activities with maximum tongue pressure, by including cross-product terms in the models (Model 2). All analyses used SAS 9.4 (SAS Institute Inc.).

RESULTS

The 1968 participants in our final sample for analysis were on average 70.6 years old (range 40 to 95), 59% female, and with a mean BMI of 23.4 kg/m^2. **Table 1** shows the characteristics of participants by sex. The mean (standard deviation, SD) maximum tongue pressure was 32.4 (10.4) kPa in men and 29.8 (9.6) kPa in women (p for difference < 0.0001). The tongue pressure was lower among older age groups in both men and women (**Figure 1**). A total of 93 (11.4%) men were classified as having a tongue pressure < 19.9 kPa, 227 (27.9%) as 20.0 to 29.9 kPa, and 495 (60.7%) as ≥30 kPa. In women, the figures were 171 (14.8%), 384 (33.3%) and 598 (51.9%). The mean

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number of family members in the household was greater for men (2.2 people) than women (2.0 people) (p = 0.001). The proportion of men having a partner was also higher (77% vs 63%) (p < 0.0001).

Table 1. Participant characteristics according to sex: The Nagasaki Islands Study 2015-2016.

Sex Category	**Women**	**Men**	p for difference	Average Maximum Tongue Pressure, kPa[a]	
N	1153	815		Women	Men
Demographics					
Age, years[a]	70.4±9.3	70.1±10.3	0.44	-	-
Lifestyle Factors					
Physical activity, N (%)					
Inactive	162 (14.1)	146 (17.9)	0.02	30.0±9.0	32.2±11.0
Active	991 (85.9)	669 (82.1)		29.8±9.7	32.5±10.3
Cigarette Smoking Status, N (%)					
Never	1084 (94.0)	220 (27.0)	<.0001	29.7±9.7	29.9±10.4
Former	44 (3.8)	428 (20.5)		32.1±10.2	32.7±10.5
Current	25 (2.2)	167 (52.5)		32.0±7.1	35.1±9.7
Alcohol Drinking Status, N (%)					
Never	910 (78.9)	230 (28.2)	<.0001	29.3±9.9	31.0±10.1
Former	29 (2.5)	93 (11.4)		30.5±9.7	28.1±11.0
Current	214 (18.6)	492 (60.4)		32.0±8.1	33.9±10.2
Physiologic Characteristics					
Maximum Tongue Pressure					
Average, kPa[a]	29.8±9.6	32.4±10.4	<.0001	-	-
<20.0 kPa, N (%)	171 (14.8)	93 (11.4)	<.0001	13.8±4.5	13.7±5.0
20 to 29.9 kPa, N (%)	384 (33.3)	227 (27.9)		25.5±2.9	25.8±2.7
30 to 39.9 kPa, N (%)	452 (39.2)	300 (36.8)		34.8±2.8	34.8±2.7
≧40.0 kPa, N (%)	146 (12.7)	195 (23.9)		44.6±4.0	45.5±5.0
Body Mass Index, kg/m^2 [a]	23.2±3.5	23.8±3.0	<.0001	-	-
Hypertension Medication, N (%)					
Yes	540 (46.8)	393 (48.2)	0.54	29.2±10.2	31.9±10.8
No	613 (53.2)	422 (51.8)		30.4±9.1	32.9±10.1
Prevalent Diabetes, N (%) [b]					

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Yes	121 (10.5)	117 (14.4)	0.01	30.7±9.7	31.7±10.6
No	1032 (89.5)	698 (85.6)		29.7±9.6	32.5±10.4
History of Stroke, N (%)					
Yes	30 (2.6)	39 (4.8)	0.01	29.4±7.7	29.7±10.5
No	1123 (97.4)	776 (95.2)		29.8±9.7	32.6±10.4
History of Respiratory Disease, N (%)					
Yes	30 (2.6)	25 (3.1)	0.54	30.0±9.9	30.2±9.0
No	1123 (97.4)	790 (96.9)		29.8±9.6	32.5±10.5
Psychologic Characteristics					
Psychological distress (K6 score)[a]	1.4±2.7	1.1±2.5	0.01	-	-
Social Environments					
Number of family members in the household [a]	2.0±1.0	2.2±0.8	0.001	-	-
Marital Status, N (%)					
Having a partner	726 (63.0)	629 (77.2)	<.0001	30.3±9.5	32.5±10.2
No partner	427 (37.0)	186 (22.8)		29.0±9.8	32.1±11.1
Participation in leisure activities, N (%)					
Yes	945 (82.0)	661 (81.2)	0.67	30.1±9.7	32.8±10.4
No	208 (18.0)	153 (18.8)		28.6±9.3	30.7±10.6
Having a Social network with neighbors, N (%)					
Yes	1001 (86.8)	660 (81.0)	0.0004	30.2±9.4	33.0±10.3
No	152 (13.2)	155 (19.0)		27.5±10.6	30.0±10.8
Having a Social network beyond neighbors, N (%)					
Yes	1062 (92.1)	724 (88.8)	0.01	30.0±9.6	32.7±10.4
No	91 (7.9)	91 (11.2)		28.2±9.9	30.4±10.3

[a] Represented as mean±SD.

[b] Diabetes was defined as hemoglobin A1c ≥6.5%, or medication use for diabetes.

Social Environment and Maximum Tongue Pressure among Participants

Multivariable adjusted linear regression analysis showed that having a social network involving neighbors and participation in leisure activities were positively

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associated with higher tongue pressure. The multivariable adjusted parameter estimates (B) were 2.43 (p = 0.0001) and 1.58 (p = 0.005) (**Table 2**, Model 2). The number of family members in the household, marital status and having a social network beyond neighbors were not associated with maximum tongue pressure. The associations did not change when we included number of family members in the household (Model 3) and marital status (Model 4) separately.

Using Wilcoxon rank-sum test, the number of family members in the household was larger for participants with a partner than those without ($p < 0.0001$). The average number of family members living in the household was 2.08±0.93, and 87% of participants who were living with someone were married. Using χ^2 tests, marital status (having a partner) was associated with taking part in leisure activities and having social networks with/beyond neighbors in men (all $p < 0.0001$), but not in women. Having social networks with neighbors was associated with taking part in leisure activities and having social networks beyond neighbors in both men and women. Having social networks with/beyond neighbors was also associated with taking part in leisure activities in both sexes.

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Table 2. Association of Social Environments with Maximum Tongue Pressure: The Nagasaki Islands Study 2015-2016.

	Model 1					Model 2					Model 3					Model 4				
Social Environments	β	B	95 % CI	p value	R^2	β	B	95 % CI	p value	R^2	β	B	95 % CI	p value	R^2	β	B	95 % CI	p value	R^2
TOTAL																				
Number of family members in the household	-0.04	-0.45	(-0.97, 0.07)	0.09		-0.04	-0.44	(-0.95, 0.07)	0.09		-0.03	-0.32	(-0.78, 0.15)	0.18		-	-	-	-	
Marital Status	0.02	0.49	(-0.52, 1.50)	0.34		0.03	0.59	(-0.42, 1.59)	0.25		-	-	-	-		0.01	0.30	(-0.62, 1.21)	0.53	
Participation in leisure activities	**0.07**	**1.90**	**(0.78, 3.01)**	**0.001**	0.12	**0.06**	**1.58**	**(0.48, 2.68)**	**0.005**	0.15	**0.06**	**1.60**	**(0.51, 2.70)**	**0.004**	0.15	**0.06**	**1.61**	**(0.52, 2.71)**	**0.004**	0.15
Social network with neighbors	**0.09**	**2.60**	**(1.35, 3.85)**	**<.0001**		**0.09**	**2.43**	**(1.19, 3.67)**	**0.0001**		**0.09**	**2.41**	**(1.18, 3.65)**	**0.0001**		**0.09**	**2.37**	**(1.14, 3.60)**	**0.0002**	
Social network beyond neighbors	0.02	0.55	(-1.01, 2.11)	0.49		0.01	0.23	(-1.30, 1.77)	0.77		0.01	0.32	(-1.21, 1.85)	0.68		0.01	0.36	(-1.17, 1.88)	0.64	
Women																				
Number of family members in the household	-0.01	-0.13	(-0.77, 0.51)	0.69		-0.02	-0.18	(-0.82, 0.46)	0.58		-0.02	-0.23	(-0.81, 0.35)	0.44		-	-	-	-	
Marital Status	-0.02	-0.34	(-1.62, 0.93)	0.60		-0.01	-0.24	(-1.51, 1.04)	0.72		-	-	-	-		-0.02	-0.30	(-1.47, 0.86)	0.61	
Participation in leisure activities	**0.06**	**1.61**	**(0.18, 3.03)**	**0.03**	0.08	0.06	1.42	(-0.01, 2.84)	0.05	0.11	0.06	1.41	(-0.01, 2.83)	0.05	0.11	0.06	1.41	(-0.02, 2.83)	0.05	0.10
Social network with neighbors	**0.10**	**2.73**	**(1.07, 4.39)**	**0.001**		**0.09**	**2.67**	**(1.00, 4.33)**	**0.00**		**0.09**	**2.68**	**(1.01, 4.34)**	**0.00**		**0.09**	**2.63**	**(0.97, 4.29)**	**0.00**	
Social network beyond neighbors	0.03	1.15	(-0.93, 3.23)	0.28		0.03	1.17	(-0.90, 3.23)	0.27		0.03	1.13	(-0.92, 3.19)	0.28		0.03	1.23	(-0.82, 3.27)	0.24	
Men																				
Number of family members in the household	**-0.08**	**-1.03**	**(-1.92, -0.14)**	**0.02**		-0.07	-0.81	(-1.68, 0.07)	0.07		-0.03	-0.37	(-1.17, 0.44)	0.37		-	-	-	-	
Marital Status	**0.11**	**2.65**	**(0.85, 4.45)**	**0.004**	0.14	**0.09**	**2.26**	**(0.47, 4.04)**	**0.01**	0.18	-	-	-	-	0.17	0.06	1.61	(-0.02, 3.23)	0.05	0.18
Participation in leisure activities	**0.08**	**2.12**	**(0.35, 3.90)**	**0.02**		0.06	1.73	(-0.02, 3.48)	0.05		**0.07**	**1.90**	**(0.15, 3.65)**	**0.03**		**0.07**	**1.89**	**(0.15, 3.63)**	**0.03**	
Social network with neighbors	**0.09**	**2.43**	**(0.51, 4.34)**	**0.01**		**0.08**	**2.13**	**(0.25, 4.02)**	**0.03**		**0.08**	**2.14**	**(0.25, 4.03)**	**0.03**		**0.08**	**2.04**	**(0.15, 3.92)**	**0.03**	

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Social network beyond neighbors	-0.01	-0.26	(-2.66, 2.14)	0.83		-0.03	-1.02	(-3.39, 1.35)	0.40		-0.02	-0.74	(-3.11, 1.63)	0.54		-0.03	-0.96	(-3.32, 1.40)	0.43	

The number of family members in the household, marital status, social networks with and beyond neighbors, and participation in leisure activities were included in Models 1–4.

[a] Model 1: Adjusted for age and sex.

[b] Model 2: Adjusted for Model 1 + lifestyle factors (physical activity, smoking status, drinking status) + physiological characteristics (body mass index) + psychological distress (K6 score) + major dysphagia risk factors (anti-hypertensive medicine use, diabetes, history of stroke, respiratory disease)

[c] Models 3–4: Adjusted for the same variables in Model 2 other than number of family members in the household and marital status, which were separately included in Models 3 and 4 to avoid over-adjustment.

B = parameter estimate. β = standardized parameter estimate. R^2 = adjusted R-squared.

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Sex-Specific Association in Social Environment and Maximum Tongue Pressure

In the sex-specific multivariable adjusted linear regression analyses, the associations between maximum tongue pressure and either social networks involving neighbors or participation in leisure activities were similar to the combined figures for women and men. The multivariable adjusted B-values were 2.67 (p = 0.002) and 1.42 (p = 0.05) for women, and 2.13 (p = 0.03) and 1.73 (p = 0.05) for men (**Table 2**, Model 2). Having social networks beyond neighbors was not associated with tongue pressure at all, whereas number of family members in the household tended to be negatively associated (B = −0.81, p = 0.07), and marital status (having a partner) was significantly positively associated with higher tongue pressure in men (B = 2.26, p = 0.01), but not women (B = −0.18, p = 0.58, and B = −0.24, p = 0.72). When we separately included number of family members in the household (Model 3) and marital status (Model 4), the associations were attenuated in men, but the attenuation did not alter the relationships of social networks and participation in leisure activities with tongue pressure.

In sensitivity analyses excluding participants with stroke or respiratory disease to exclude influences on tongue pressure or overall oral function from those diseases or associated medication, neither the overall nor sex-specific results changed (**Supplemental Table 1**). There was no evidence that sex modified the relationship of number of family members in the household, networks with and beyond neighbors and leisure activities with maximum tongue pressure (interaction p = 0.87, p = 0.36, p = 0.19, p = 1.00). It did, however, show a borderline significant interaction in the association between marital status and maximum tongue pressure (interaction p = 0.059).

DISCUSSION

In this population-based study of 1968 participants, having a social network involving neighbors and participating in leisure activities were associated with higher maximum tongue pressure. This association was independent of age, sex, body mass index, psychological distress, behavioral factors, and other risk factors for dysphagia. Having a partner was associated with greater tongue pressure in men only. This is the first evidence of which we are aware that suggests that social environment may influence tongue pressure. It supports previous reports suggesting the importance of social ties and taking part in daily leisure activities in improving or maintaining tongue function and possible prevention of dysphagia and aspiration.

Our results are consistent with previous studies on daily and social activities, in

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which oral function was assessed by self-reported questionnaire.[35,36] Kamakura et al carried out a questionnaire survey among 769 local senior club members, and reported that factors related to daily activities such as time spent outside the home each day, higher frequency of loud laughing, and enjoying eating were associated with a lower proportion of swallowing problems (self-reported choking on food).[35] A previous community-based study of 1405 randomly selected older people showed that not participating in social activities was linked to a self-assessed masticatory problem.[37]

Although the mechanisms underlying the association between social networks or participation in leisure activities and tongue pressure have not been fully elucidated, physiological, behavioral, and psychological factors are likely to be involved. Higher activity in muscles around the pharynx and mouth may have a positive effect on tongue function. People who are living with family members and have close neighbors may communicate with others more often, and particularly have more opportunity to eat together, have conversations and laugh. Eating with someone could have a positive influence on oral function via increased saliva production and higher tongue activity, as well as having a preventive effect on depression.[38] It may also be related to better nutrition, eating behavior, dietary composition and energy levels,[39] as well as more social interactions.[40] A link was identified between laughter and enjoying eating and lower self-reported symptoms of aspiration in an epidemiological study.[35]

The difference in frequency of social interactions in daily life could explain why only social networks involving neighbors, and not those beyond, were associated with higher tongue pressure in this study. The influence of social networks beyond neighbors on tongue pressure could depend on both the type of relationship (close family, wider relatives, or friends) and frequency of meeting, but the results suggest a possibility that an effective public health intervention to prevent oral frailty and subsequent aspiration might focus on social networks involving neighbors. Hikichi et al. reported that community intervention may be effective in encouraging social participation among Japanese older people, and helping to prevent the onset of functional disability.[16] That study confirmed that the number of community-based centers for older people, so-called ‘community salons’, within 350 meters of the home was related to frequency of participation. It also found that incidence of functional disability among residents who participated in ‘community salons’ three or more times over the 4.9 years of follow-up was reduced by 50% over those who participated twice or less. The result was similar even when the researchers accounted for the possibility of selection bias by using propensity score matching analysis and instrumental variable analysis.[16]

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The number of family members in the household was not associated with tongue pressure in the combined analysis, and a negative association was observed in men. We think this may be partially because of possible differences in duration of living with family members. There is also a possibility of reverse causation: some people may have started to live with family members as a result of decreased ability to perform activities of daily living. We did not collect any detailed information about leisure activities, but these could be related to higher social interaction, physical/mental activity, self-actualization or 'Ikigai', a comprehensive Japanese concept encompassing the 'meaning of life' and/or 'purpose in life'.[41] Large population-based longitudinal studies of older people in Japan have reported that having hobbies or social participation may be effective in decreasing the risk of functional disability,[42] and progression of senility associated with dementia.[43] A previous report from the Japanese government showed that people with more friends had a stronger feeling of 'Ikigai'.[36] The proportion participating in leisure activities was higher in participants with social networks both with and beyond neighbors in our study, but we believe the associations with higher tongue pressure are likely to be independent. The reason for the sex difference in the association between marital status and tongue pressure is unknown, but cultural gender roles in Japan and health-related behaviors could partially mediate the association. As men more often work outside the home, and women are more involved in household chores in Japan,[30] women may have more opportunity to communicate with their neighbors than men, regardless of marital status. Our results suggested that the proportion having social networks and participating in leisure activities were higher among married men than unmarried. Health-compromising behaviors (e.g., smoking, heavy drinking, lower vegetable consumption and less frequent dental visits) have previously been shown to be related to marital status in both men[44,45] and women.[45,46] Marital termination (e.g., divorce and widowhood) were associated with an elevated mortality risk for men, but not for women in a large Japanese cohort study.[47]

The association between tongue pressure and both social networks and participation in leisure activities were independent of psychological distress in this study. Psychological distress could influence oral function via lower frequency and number of communications, related to reduced social interaction,[48] as well as altered health-promoting behaviors (e.g., brushing teeth, consuming a healthy diet, exercising, not smoking). Medication use for depression is also known to be a risk factor for dysphagia and aspiration because of the muscle relaxant effect. A future study examining links with medication use for depression may be helpful.

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Strengths and Limitations

Our study had several limitations. Social networks and participation in leisure activities were assessed using a dichotomous answer, so detailed information about the social network quality (e.g., relationship or closeness) and quantity (e.g., number involved in the social network, and frequency of communications), or the type of activity (e.g., solo or social activity) were not available in this study. However, the simplicity of the question is useful in identifying people with at least one social network or leisure activity. Further studies will be needed to investigate the influence of various detailed aspects of social networks and leisure activities on tongue pressure. Second, measurement error and subsequent misclassification almost certainly occurred, because the social environment data were self-reported. Participants' answers were about their mental and social environment at the point of response, and further studies will therefore be needed to assess the duration of the situation (e.g., how long they have been living alone) and timing (e.g., when they lost their partner, or retired). Third, tongue-pressure measurement has good reproducibility and high correlations with other objective measurements for oral functions,[21] but unmeasured characteristics of the participants like cognitive decline, or oral conditions like denture use could have influenced the measurement. Fourth, although we adjusted for potential confounders including disease-related dysphagia risk (stroke, and respiratory disease), there may have been other residual or unmeasured confounders (for example, other diseases like dementia, epilepsy, medication use including anticholinergics, diuretics, antidepressant or sleep medicine, and diet and lifestyle changes) that influenced the association between social environment and tongue pressure. Fifth, causal relationships cannot be identified from cross-sectional analyses. There is a possibility of reverse causation or bi-directional relationships.[49] For example, people without oral frailty may maintain larger social networks or participate in more daily activities, or some people could have started to live with family members as a result of weakened physical function, but this cannot be assessed. Sixth, the study response rate was under 20% in the target population in the city, which may have led to selection bias. However, we believe that the high rate of agreement to participate (94%) is likely to have minimized any bias among the population. Seventh, although age-related social environment differences and/or tongue pressure (**Figure 1**) may have influenced the associations, we could not assess the most appropriate age cut-off point for the associations, partly because we have limited population data to explore this. Further research with a larger sample sizes or prospective design would be needed to investigate whether there are age-specific

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associations. Last, our study subjects were from a rural area in Japan, in which social ties with neighbors could be stronger than those in urban areas. Further research would be needed to assess the generalizability of the study.

The strengths of our study included objective measurement of tongue pressure using population-based samples, a comprehensive assessment of social environment focusing on family structure, social networks within and beyond neighbors, and participation in leisure activities, and standardized data collection for potential risk factors for dysphagia including psychological distress, and physical and behavioral characteristics.

CONCLUSIONS

Having a social network involving neighbors and taking part in leisure activities were independently associated with higher maximum tongue pressure in a sample of community-dwelling men and women. Marital status may be also an important factor in maintaining tongue pressure among men. Further studies will be needed to assess the impact of particular elements of the social environment on tongue pressure, including social network size, quality and duration of the situation, or type of activities, using a prospective design. This study, however, suggests the importance of family structure including marital status, social networks with and beyond neighbors, and participation in leisure activities for risk assessment of oral frailty.

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Competing interests

All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

Authors' contributions

MN conceived the study, analyzed and interpreted the data, drafted the manuscript, and provided statistical expertise. MN, MH, NT, MT, JK, HY, KK, SS, ZK, TS, TM acquired the data. MN, MH, NT, MT, JK, HY, KK, SS, SK, ZK, TS, TM interpreted the data and critically revised the manuscript. TM is guarantor for the study. All authors approved the final version of the paper.

Data sharing statement: Researchers can apply for data by submitting a proposal to ritouken@vc.fctv-net.jp. After agreement of the proposed analysis by the steering committee, and approval by the executive committee, collaborative researchers receive participants' data based on the proposed analysis.

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Figure 1. Sex-specific maximum tongue pressure by age group: The Nagasaki Islands Study 2015–2016.

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Figure 1. Sex-specific maximum tongue pressure by age group: The Nagasaki Islands Study 2015–2016.

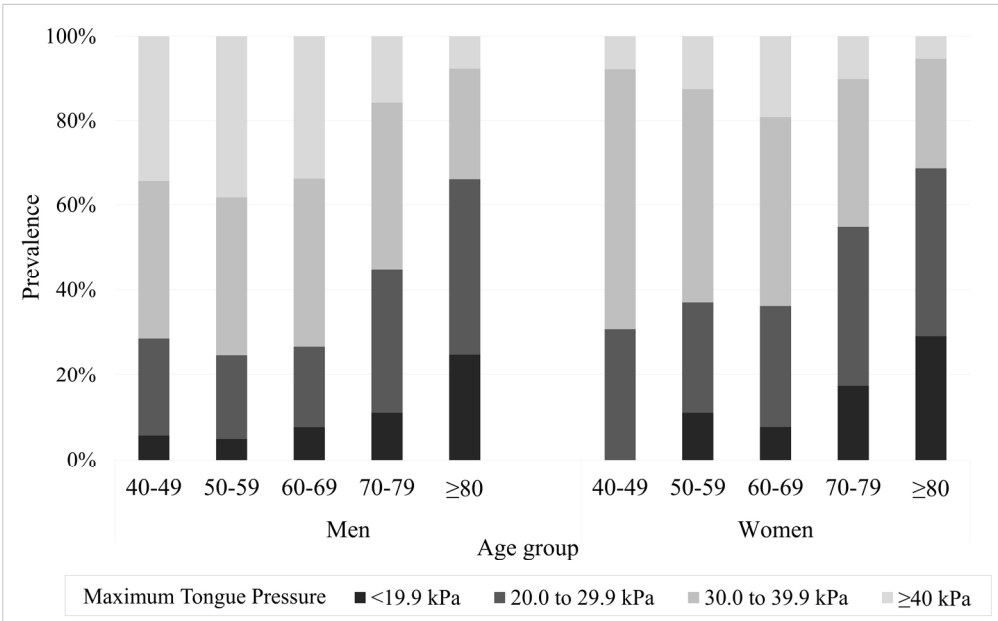

Figure 1. Sex-specific maximum tongue pressure by age group: The Nagasaki Islands Study 2015–2016.

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Social Networks, Leisure Activities and Maximum Tongue Pressure: Cross-sectional Associations in The Nagasaki Islands Study

Mako Nagayoshi, Miho Higashi, Noboru Takamura, Mami Tamai, Jun Koyamatsu, Hirotomo Yamanashi, Koichiro Kadota, Shimpei Sato, Shin-ya Kawashiri, Zenya Koyama, Toshiyuki Saito, Takahiro Maeda

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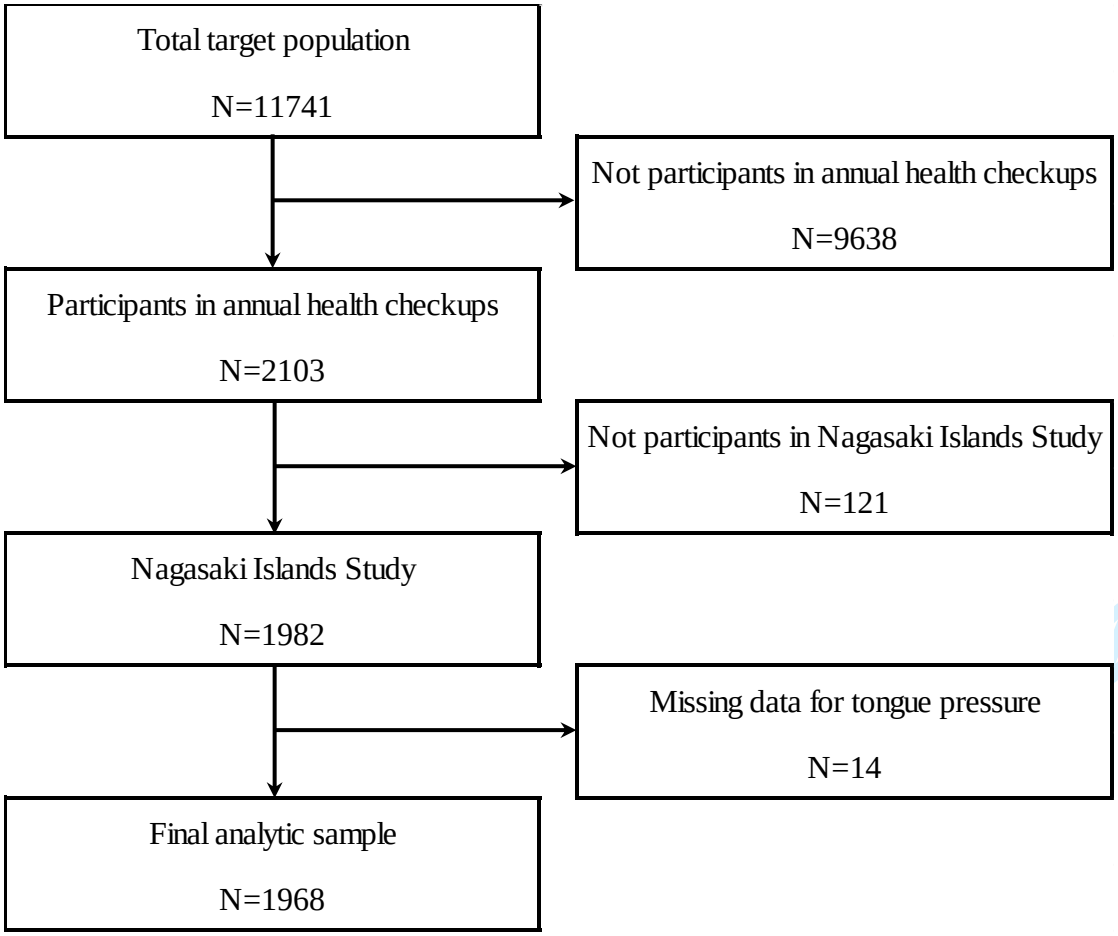

Supplemental Figure 1. Study sample flow chart.

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Supplemental Table 1. Association of Social Environments with Maximum Tongue Pressure among Participants without History of Stroke or Respiratory Disease: The Nagasaki Islands Study 2015-2016.

	Model 1					Model 2					Model 3					Model 4				
Social Environments	β	B	95 % CI	p value	R^2	β	B	95 % CI	p value	R^2	β	B	95 % CI	p value	R^2	β	B	95 % CI	p value	R^2
TOTAL																				
Number of family members in the household	**-0.05**	**-0.62**	**(-1.18, -0.06)**	**0.03**		**-0.06**	**-0.65**	**(-1.20, -0.10)**	**0.02**		**-0.04**	**-0.50**	**(-1.00, 0.00)**	**0.05**		-	-	-	-	
Marital Status	0.03	0.56	(-0.50, 1.61)	0.30		0.03	0.65	(-0.40, 1.70)	0.22		-	-	-	-		0.01	0.19	(-0.76, 1.13)	0.70	
Participation in leisure activities	**0.08**	**1.99**	**(0.84, 3.14)**	**0.001**	0.12	**0.06**	**1.67**	**(0.54, 2.81)**	**0.004**	0.16	**0.07**	**1.71**	**(0.57, 2.84)**	**0.003**	0.16	**0.07**	**1.73**	**(0.60, 2.86)**	**0.003**	0.15
Social network with neighbors	**0.10**	**2.65**	**(1.37, 3.94)**	**<.0001**		**0.09**	**2.45**	**(1.17, 3.72)**	**0.0002**		**0.09**	**2.43**	**(1.16, 3.71)**	**0.0002**		**0.09**	**2.36**	**(1.09, 3.64)**	**0.0003**	
Social network beyond neighbors	0.01	0.46	(-1.15, 2.08)	0.57		0.00	0.12	(-1.46, 1.71)	0.88		0.01	0.21	(-1.37, 1.79)	0.79		0.01	0.26	(-1.32, 1.84)	0.75	
Women																				
Number of family members in the household	-0.02	-0.25	(-0.95, 0.46)	0.49		-0.04	-0.38	(-1.08, 0.32)	0.29		-0.04	-0.45	(-1.08, 0.18)	0.16		-	-	-	-	
Marital Status	-0.02	-0.48	(-1.82, 0.86)	0.48		-0.01	-0.29	(-1.63, 1.05)	0.67		-	-	-	-		-0.03	-0.54	(-1.75, 0.66)	0.38	
Participation in leisure activities	**0.06**	**1.63**	**(0.15, 3.10)**	**0.03**	0.08	0.06	1.44	(-0.04, 2.91)	0.06	0.11	0.06	1.43	(-0.05, 2.90)	0.06	0.11	0.06	1.42	(-0.05, 2.90)	0.06	0.10
Social network with neighbors	**0.10**	**2.84**	**(1.13, 4.54)**	**0.001**		**0.09**	**2.69**	**(0.98, 4.40)**	**0.002**		**0.09**	**2.69**	**(0.98, 4.40)**	**0.002**		**0.09**	**2.62**	**(0.91, 4.33)**	**0.003**	
Social network beyond neighbors	0.04	1.27	(-0.88, 3.41)	0.25		0.04	1.37	(-0.75, 3.50)	0.21		0.04	1.34	(-0.78, 3.46)	0.22		0.04	1.45	(-0.67, 3.57)	0.18	
Men																				
Number of family members in the household	**-0.10**	**-1.22**	**(-2.14, -0.30)**	**0.01**		**-0.08**	**-1.00**	**(-1.90, -0.10)**	**0.03**		-0.04	-0.50	(-1.33, 0.34)	0.24		-	-	-	-	
Marital Status	**0.12**	**3.08**	**(1.22, 4.95)**	**0.001**		**0.10**	**2.59**	**(0.74, 4.43)**	**0.006**		-	-	-	-		**0.07**	**1.79**	**(0.10, 3.48)**	**0.04**	
Participation in leisure activities	**0.09**	**2.36**	**(0.52, 4.20)**	**0.01**	0.14	**0.07**	**1.96**	**(0.16, 3.77)**	**0.03**	0.19	**0.08**	**2.16**	**(0.35, 3.97)**	**0.02**	0.18	**0.08**	**2.15**	**(0.35, 3.95)**	**0.02**	0.18
Social network with neighbors	**0.10**	**2.55**	**(0.58, 4.52)**	**0.01**		**0.08**	**2.19**	**(0.25, 4.12)**	**0.03**		**0.08**	**2.15**	**(0.21, 4.09)**	**0.03**		**0.08**	**2.04**	**(0.11, 3.98)**	**0.04**	
Social network beyond neighbors	-0.02	-0.75	(-3.24, 1.74)	0.55		-0.05	-1.65	(-4.11, 0.81)	0.19		-0.04	-1.27	(-3.73, 1.18)	0.31		-0.05	-1.54	(-3.99, 0.92)	0.22	

The number of family members in the household, marital status, social networks with and beyond neighbors, and participation in leisure activities were included in Models 1–4.

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[a] Model 1: Adjusted for age and sex.

[b] Model 2: Adjusted for Model 1 + lifestyle factors (physical activity, smoking status, drinking status) + physiological characteristics (body mass index) + psychological distress (K6 score) + major dysphagia risk factors (anti-hypertensive medicine use, diabetes)

[c] Models 3–4: Adjusted for the same variables in Model 2 other than number of family members in the household and marital status, which were separately included in Models 3 and 4 to avoid over-adjustment.

B = parameter estimate. β = standardized parameter estimate. R^2 = adjusted R-squared.

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STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1, 2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-8
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	N/A
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	N/A
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5-8
Bias	9	Describe any efforts to address potential sources of bias	7-8, 16-17
Study size	10	Explain how the study size was arrived at	5-6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7-8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7-8
		(*b*) Describe any methods used to examine subgroups and interactions	7-8
		(*c*) Explain how missing data were addressed	6
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	5-6, Supplemental Figure 1
		(*e*) Describe any sensitivity analyses	8

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Results			**Page #**
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	5-6, Supplemental Figure 1
		(b) Give reasons for non-participation at each stage	5-6
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exosures and potential confounders	8-11, Table 1, Figure 1
		(b) Indicate number of participants with missing data for each variable of interest	6
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	N/A
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	N/A
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	N/A
		Cross-sectional study—Report numbers of outcome events or summary measures	8-13, Table 1-2, Supplemental Table 1
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	8, Table 2, Supplemental Table 1
		(*b*) Report category boundaries when continuous variables were categorized	N/A
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	13, Supplemental Table 1
Discussion			
Key results	18	Summarise key results with reference to study objectives	13-17
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16-17
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13-17
Generalisability	21	Discuss the generalisability (external validity) of the study results	16-17
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article	17-18

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*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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